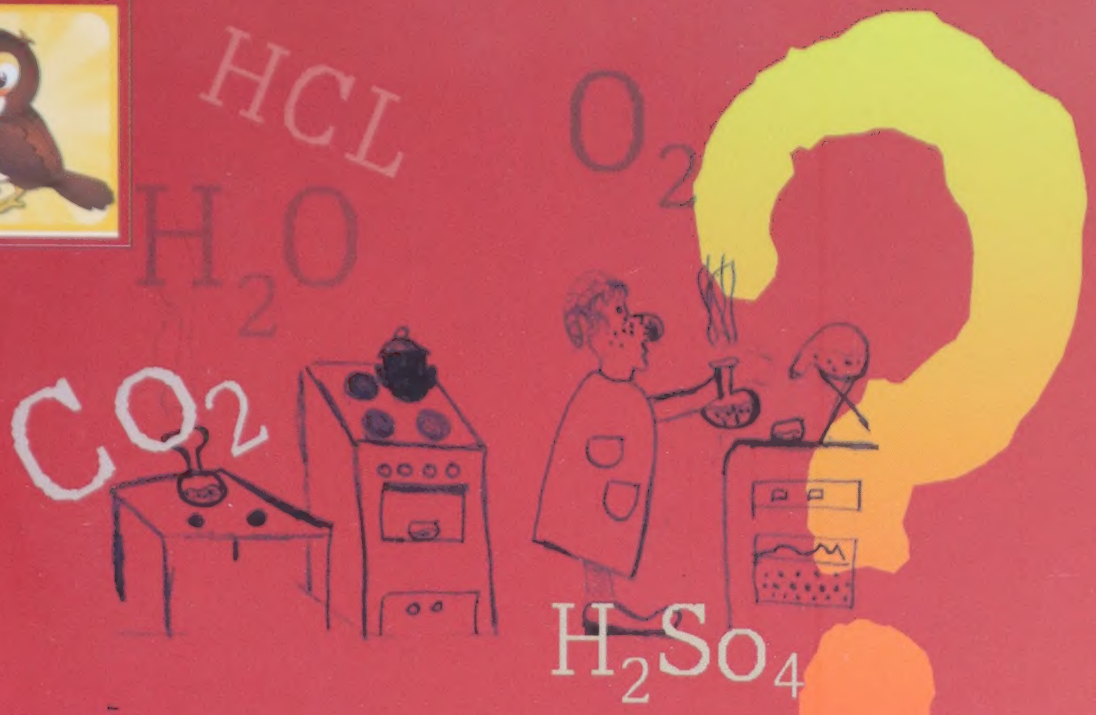

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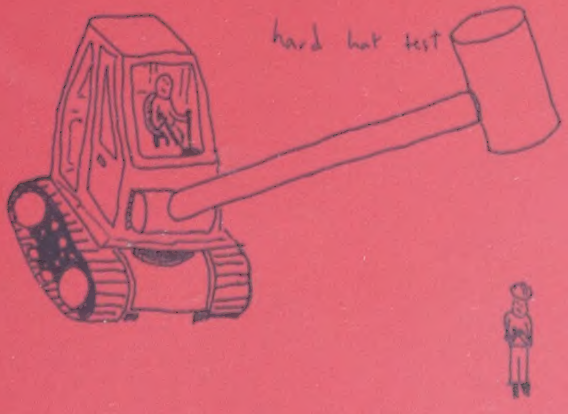

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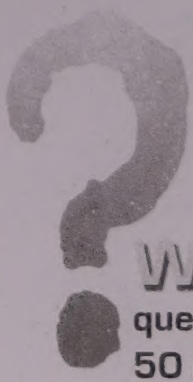

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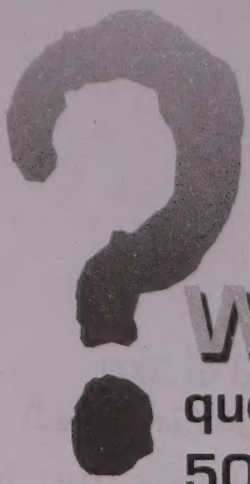

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BAL PHONDKE

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To

K. Santhanam
(Santy)
In Remembrance of times
WHEN
we had all the fun together

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Preface

Curiosity may have killed the cat. Even so, it has helped human beings acquire immense knowledge. Human beings are curious by nature. A child is forever searching its environment to get to know it better and thus equip itself with all the tools that would make its sojourn on this earth smooth and easy. In fact, the bug of curiosity that bites in early life makes its impact even more intense as time progresses. Humans, thus, remain forever in quest of answers to all sorts of questions that continuously plague them.

There are six handy helpmates that make one's task easier, five W's and an H—What, Why, When, Who, Where and How. There is no dearth of resources that provide answers to questions starting with What, Why and How. Not all of these offer most satisfactory or logical solutions to the conundrums. Still, quite a few of these do attempt to make available answers that are scientifically as accurate as possible.

In that respect questions beginning with When, Who and Where appear to be treated as poor cousins. They are not attempted with the same gusto that treat the What's, Why's and How's. This is somewhat unfair because many of these questions from the second string, as it were, are as intriguing as those that constitute the front ranks.

One might have a prima facie impression that queries commencing with When would all deal with events that have occurred in the past. If so, one may not necessarily be interested in those unless one is history-minded. This is not

true. Many of these relate to events that are continuously unfolded before us: 'When does water boil?' or 'When does a reactor go critical?' are firmly rooted in present reality.

Again not all questions contend with issues ensconced in the realms of science and technology. Many emerge from apparently mundane experiences that mere mortals like us have in their seemingly uneventful life: 'When does a child start recognising faces?' or 'When do birds sing?' represent this kind. And then there are some like 'When does life begin?', or 'When would mankind be extinct?' that might appear philosophical. On the other hand, those like 'When does cheese run?' or 'When does a Mexican wave erupt?' may even sound frivolous.

Whatever their nature, they deserve logical and scientifically acceptable answers. This is what '*When...*' attempts. It is possible that reading these could whet your appetite rather than quench your thirst. That would indeed be a welcome response.

BAL PHONDKE

1

WHEN DID THE MURDER TAKE PLACE?

A dead man tells no tales. This is what everyone would like to believe. That is why the culprit thinks that he or she can, quite literally, get away with murder. But not so fast. A good forensic scientist can always make the dead body talk. And how! As a result, the alibis so carefully built up by a number of killers have been blown away to smithereens.

Determining exactly when the murder took place has a crucial role to play in any investigation. Once the time of death is fixed beyond reasonable doubt the activities of all suspects at the precise time can be looked into. Thus the short list of suspects can be pared down further enabling one to zero in on the real culprit.

Three different properties of the body come to the help of the investigating doctor. Body of a living person is supple and soft. Death robs it of this property. It becomes stiff. In medical parlance this phenomenon is described as setting in of *rigor mortis*. It does not happen immediately after one expires. It takes some time. So assessing the state of *rigor mortis* provides a clue to the time that has elapsed since the victim breathed her last.

Another pointer is given by the extent of lividity. It is also called *livor mortis*. One of the signs of death, it is settling of the blood in the lower dependent portion of the body. This leads to a purplish red discoloration of the skin. This is because when the heart is no longer agitating the blood, heavy red blood cells sink through the serum by action of gravity. This discoloration does not occur in the areas of the body that are in contact with the ground or

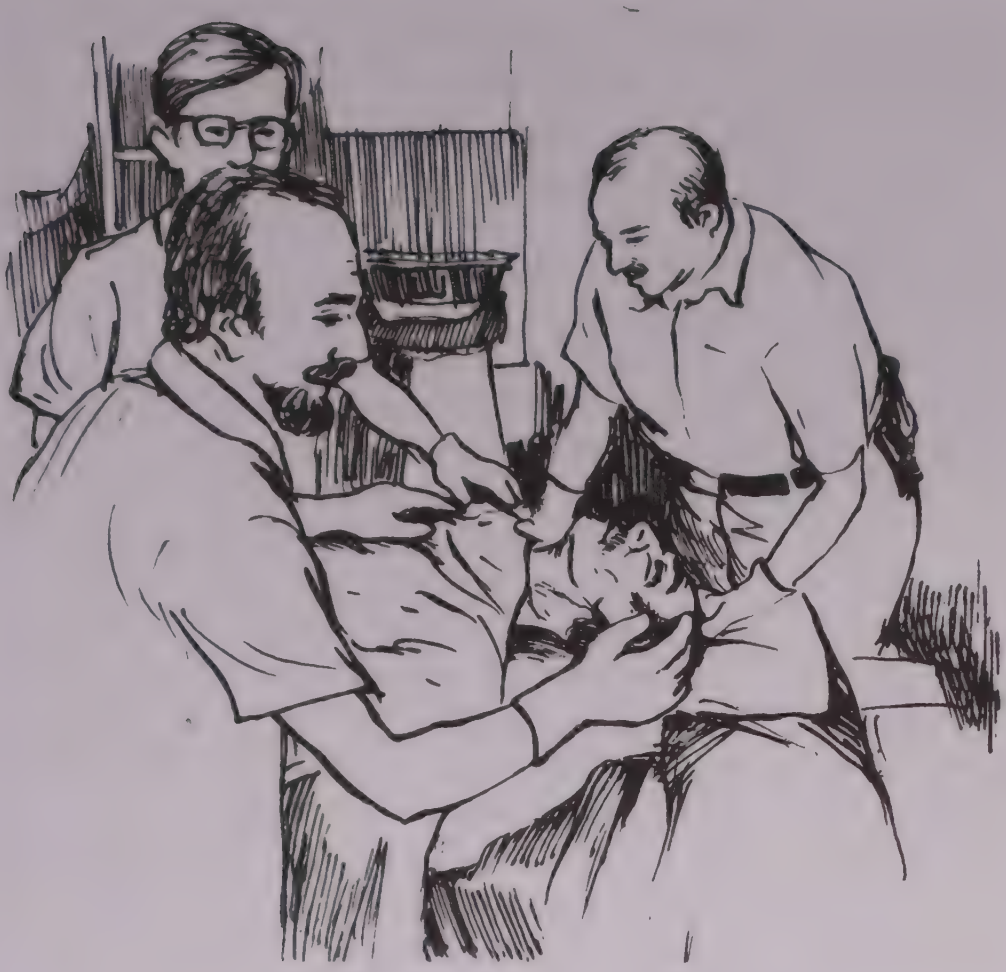
another object, as the capillaries there are compressed. The rate at which skin thus pales allows the doctor to calculate the time that has elapsed since the person ceased to live.

Yet another indication can be had from the temperature of the body. When alive, the body maintains its temperature at a healthy 98.4 degrees Fahrenheit. But once death occurs the thermostatic mechanism that keeps the body temperature at that level irrespective of the ambient temperature is no longer operative. So the body obeys laws of physics and brings about an equilibrium with the temperature of the surroundings. Except for peak summer the temperature at any place is usually significantly less than the body temperature. So it cools down. The rate at which this loss of heat takes place is now known. The body temperature starts getting lowered at the rate of 0.27 degrees Celsius per hour. So the forensic scientist measures the core temperature of the body by inserting a thermometer deep inside the rectum. Alternatively he may make a small cut under the ribs and place the thermometer through it close to the liver.

Thus the dead body itself is made to tell us when the murder took place.

That is possible provided of course the corpse is found within a reasonable time after the heinous crime. That does not always happen. Instances where body of the deceased is discovered long after the event are not uncommon. At such times all the tools normally used by the investigating pathologist are blunted. She has to resort to other ingenious devices.

One such very perplexing problem confronted scientists from Magdeburg in Germany. Towards the end of the twentieth century, construction workers digging the foundation for a new structure stumbled onto a burial pit. Normally all dead bodies are buried in official cemeteries in that country. Any such unauthorised burial always evokes considerable interest because of the possibility that it might contain bodies of Hitler and his mistress Eva Braun. They



were reported to have committed suicide on the eve of the fall of Berlin at the end of the War. But their corpses were never found. People had thought that they were hurriedly buried in some unknown place. So whenever such unaccounted for burial ground is discovered, the morbid hope of finding those corpses raises its head.

The Magdeburg pit was no exception. However, such hopes were soon dashed if only for the gruesome fact that it contained not two but thirty-two bodies. As a matter of fact they were not bodies for there were no coffins. There were only skeletons. Nobody had a clue to their identity, much less the circumstances that led to their collective and unceremonious burial.

That does not mean that there were no conjectures.

There were not one but two strong suspects for being perpetrators of the offence. One was the obvious one, the infamous Gestapo. They were responsible for doing away with a whole multitude of people. Six million Jews were sent to the gas chambers in various concentration camps. But their wrath was not restricted to Jews alone. There were others belonging to a number of racial and ethnic groups who had suffered a similar fate. It was true that almost all of these murders were committed behind closed walls of the concentration camps. However, once the tide of the War had turned and the Germans were on the retreat, the Gestapo, either in desperation or blind fury, had resorted to killing all those that incurred their displeasure outside these camps. They had dumped the corpses hurriedly in wayside pits. Since Magdeburg was in that zone from where reports of such dastardly acts had emanated, the possibility that the unfortunate victims were German nationals put to death by the Gestapo could not be ruled out.

There was yet another likelihood. Once the War was won, the allies no longer remained united. A cold war had set in with the Soviet Union on one side and the rest on the other. Sharing the spoils of victory, eastern Europe, and in particular East Germany, had come under the Russian jurisdiction. In order to strengthen their hold and perpetuate their newly built 'empire', the Russians had resorted to strong arm tactics. ***Smersh***, the secret police organisation, whose name quite literally meant 'Death to Spies', had put even the Gestapo to shame. Anyone from the occupied territories who dared to challenge the authority was awarded the death sentence without any trial. Even those among their own ranks who refused to follow the inhuman orders were not spared. East Germany was supposed to be littered with hastily dug burial pits holding the remains of such victims. So the one at Magdeburg could equally well have been the uneasy final resting place for Russian nationals who had fallen foul of the authorities.

The skeletal remains made no distinction between

Germans and Russians. Moreover the death had occurred some years earlier. So none of the normal forensic tools could be of any help. Some other ingenious way had to be sought.

Apart from the possible different nationalities of the victims there were differences in the time of the deaths. The Germans had committed such barbaric acts while running away from the advancing allied forces. That was in the spring of 1945. If the Russians were responsible for these gruesome murders then that could have happened only in the summer of 1953. Was this difference of any significance. After all these years would any tell-tale signs be still left on the bodies of the victims?

To resolve this issue the scientists came up with a fascinating idea. The flowering period of different trees are different. At such times the winds scatter pollens of these trees over a wide area. When one breaths one also tends to inhale some of these wind borne pollen. Those who are allergic to pollen even suffer from hay fever. The scientists decided to use these pollen as their detectives. They decided to find out if the nasal cavities of these skeletons harboured any pollen. That hunch paid off. Indeed such pollen were found to have been stored in the nasal cavities of the skeletons and had stayed put after all these years.

That still was not a credible evidence. Wasn't it possible that the pollen were picked up by these cadavers from the soil that they had been lying on? Indeed, that was certainly possible. However, if that were the case then the pollen should have been found all over the body. But they were seen to be ensconced only in the nasal cavities. Obviously, they had gotten there only from air.

Even so, how was one to find out when exactly the victims were murdered. For that to be determined beyond any doubt the scientists carried out a year long experiment. They picked up a few student volunteers and asked them to collect secretions from their noses in handkerchieves. These were then dried and analysed to find out if the nature

of pollens varied according to seasons. That turned out to be the case. It also helped scientists to identify the exact source of pollens at differing seasons.

Armed with this information they turned their attention once again to the pollen collected from nasal cavities of the victims. Scrutiny of these revealed that the pollens had lodged in the nasal cavities during peak summer. The Germans could thus be exonerated and the proverbial finger could be pointed with a degree of certainty towards the Russians, the Smersh to be precise.

Thus even though almost half a century had elapsed leading to only skeletal remains of the victims, the scientists could unambiguously say when the murder was committed!

2

WHEN DID ANIMALS STEP ON THE LAND?

Those who have read Hindu mythology are well familiar with the legend of *Dashavatara*, the ten incarnations of Lord Vishnu. Some contend that therein lies the story of evolution of animals. That is debatable. Even so, there is no denying that the progression of the various incarnations in the fable does have an uncanny resemblance to the saga of animal evolution as deciphered by paleontologists.

The first incarnation is that of a fish, an aquatic animal. The next is a turtle, an amphibian, followed by a wild boar, a truly land animal and a mammal to boot. The next in line is a chimera, half lion, half human. Thereafter, there is a succession of human incarnations with increasing degrees of first physical and then intellectual as well as cultural emancipation.

There is now almost universal agreement that life evolved in the 'warm little pond' conceived by Darwin. For what can be a very long period even on the evolutionary time scale living organisms remained confined to the seas. Marine animals evolved from lowly planktons to huge sea creatures like whales and sharks. Then, late in the history of this planet, life ventured to set foot on land.

Thus emergence of living organisms on land marks an important milestone in earth's life history. Naturally one wonders when exactly did that crucial transition take place. When did animals take the tentative steps to start moving on land?

Despite intensive investigations, scientists were not able to tell that in an unequivocal manner. They had a vague

idea. Still, they were not able to produce supportive evidence. They were able to piece together a coherent credible story which indicated that lobe-finned fishes evolved into land-living creatures during the Devonian Period.

But fossil records showed a gap between *Panderichthys*, a fish that lived about 385 million years ago and which

showed early signs of evolving land-friendly features, and *Acanthostega*, the earliest known four-limbed land-living animal dating to about 365 million years ago. The intervening 20 million years constituted a dark period. Nobody could affirm with confidence about the events in that interval. All that one could say was that the animals left the secure warm seas and ventured into an unknown territory sometime during that mysterious period. Nor could anyone be sure whether *Acanthostega* were indeed the first ever land animals.

In 1999, palaeontologists Professor Neil Shubin, from the University of Chicago, and Professor Edward Daeschler, from the Academy of Natural Sciences in Philadelphia, set out to explore the Canadian Arctic in an attempt to find the 'missing link' that would explain the transition from water to land.

After several years of searching with very little success, they hit the jackpot in 2004. The really remarkable find came when one of the crew found a snout of a flat-headed animal sticking out of the side of a cliff. The team found three near-complete, well-preserved fossils of the new species, *Tiktaalik roseae*, in an area of the Arctic called the Nunavut Territory. The largest among them measured almost 3 m in length.

When they got back into the laboratory with their catch, they removed the rock from the bone. It was then that they began to find some really significant material. The creature shared some characteristics with a fish; it had fins with webbing, and scales on its back. But it also had many features in common with land animals. It had a flat crocodile-like head with eyes positioned on top and the beginnings of a neck—something not seen in fish. Looking inside the fin, one was able to see a shoulder, an elbow, and an early version of a wrist, which is very similar to that of all animals that also walk on land. Essentially it was an animal that was built to support itself on the ground. The position of the creature's eyes suggested it probably lived

in shallow water. What was significant about the animal was that it was a fossil that blurred the distinction between two forms of life—between an animal that lives in water and an animal that lives on land. This remarkable crocodile-like creature was most probably an amphibian which is a stage in-between a marine creature and a land animal.

Then came the crucial issue of dating the specimen. That was carried out with the most sophisticated techniques available for determining age of prehistoric samples. The fossil was found to be 383 million years old.

So when did animals step on to land? They took this revolutionary step around 380 million years ago.

3

WHEN ARE 22 EQUAL TO ZERO?

All men are created equal. This principle was enunciated by Plato in his *Republic*. All political parties ever since have been publicly asserting that they not only adhere to it but also consider it sacrosanct. Even so, in practice it turns out to be an entirely different story altogether. Even the proponents of the French revolution who touted the concept of 'Liberté, Egalité et Fraternité' with much fanfare put paid to the maxim at every convenient opportunity. That is why when George Orwell came up with a rider, 'All are equal but some are more equal than others', it found ready acceptance all over. Though Orwell had described it as the guiding principle of *Animal Farm*, a thinly veiled parody of the then Soviet Union, it soon became apparent that the tenet is equally applicable to many a democratic regime.

John Banzhaf described this apparent anomaly by pronouncing a mathematical expression that has since come to be known as the 'Banzhaf Index of Power'. A central concept of political sciences is political power. Banzhaf considered only those forms of power which are related to formal voting systems with 'yes-no' decisions only. Intuitively one would expect that a three times larger number of votes implies 'three times as much power'. But the situation, concerning power relations in the European Economic Union according to the Treaty of Rome (1958), made him think differently.

France, Germany and Italy had four votes each, Belgium and the Netherlands two, and Luxembourg one. Twelve of these 17 votes, the so-called quorum, were necessary to

approve a decision. If we restrict the notion of political power to the ability to contribute the decisive vote or votes to a majority constituting at least 12 votes, we see immediately that Luxembourg had absolutely no share in the political power. If there were 10 votes for or against a political decision, Luxembourg had no possibility to contribute the two missing votes for the quorum.

Of course, it could hold back its vote; but this had no formal impact on the outcome of the decision either. This poses the question, how can one formulate political power mathematically? There are several possibilities.

The Banzhaf Index is, therefore, a quantity to measure the political power of each member of a voting system. A member in a voting system is, for example, a party in a parliament or a country in a confederation. In general, each member will have a certain number of votes, and so its power will be different.

The Banzhaf Index is derived by simply counting, for each member, the number of winning coalitions in which he can participate but which are not winning if he does not participate. Consider the simple case of three parties—A, B, and C in a parliament with the following distribution of votes: A has 50 members, B has 49 and C has a lone member.

No single party is in a position to win power on its own as that needs a minimum of 51 votes. Of course, a minority government can be formed by Party A or even Party B. However, it would perpetually remain in danger of getting defeated were the other two parties to forge a united opposition front. The sword of Damocles would be constantly hanging on the uneasy head wearing the crown. So the only way out is to form a ruling alliance.

There are three possible coalitions. All three parties coming together to form the combination ABC. Alternatively A and B together can also form a winning combination or even A and C. Each of these listed winning coalitions would cease to be in a winning position if party A were to leave it. That cannot be said of either B or C. A is essential for the coalition ABC, but B and C, respectively, are not! The 'Banzhaf power' of A thus is 3, whereas the one of B and C each is 1. This yields the 'total Banzhaf power', or *Penrose number*, of 3+1+1 that is 5. The Banzhaf Index is the 'normalised' Banzhaf power. So the Banzhaf Index of party A with 50 votes is 3/5 whereas that of the other two is 1/5 each. Despite having as many as 49 votes, party B is in no better position than party C with a solitary member.

Of course, Banzhaf Index is not restricted to politics. A similar situation arises in a joint stock company. Suppose there are three shareholders in an industrial venture. One

of them, say P holds 47 per cent of the total number of shares. Another, say Q, has 48 per cent with him while the third, a minority share holder owns only 5 per cent shares. No one on his or her own can gain control of the company. For that to happen any two have to come together. That means that each one of them, irrespective of the actual number of shares with him, has an equal chance to control the company. Thus the power lying with all of them to make meaningful contribution to have a deciding say in the affairs of the company is the same. The Banzhaf Index of power is the same for everyone.

But now suppose there is some redistribution in the number of shares as a result of a split or buying on the market. Now there are four shareholders, J, K, L and M. Their respective holdings are 27, 26, 25 and 22. Again no one by himself or herself can control the company. At least two of them have to come together. If J & K or K & L or J & L come together they can get the controlling 51 per cent of the stake. But if M joins any one of them the combination will still fall short of winning majority. They will still need a third partner. But in that case the other two can leave out M and still be in a commanding position. They can do without the contribution of M He is not needed. Thus his ability to make a meaningful contribution to decision making is zero. Even though he has as many 22 votes, only a few less than any of the other contenders; his Banzhaf Index is zero. On the other hand, with only a handful of shares more than M the other three enjoy equal and high status.

Thus, it is not the actual number of members belonging to a party that makes the difference between power and no power. It is their relative ability to influence a decision as reflected in the Banzhaf Index. If it is not favourable then having 22 members is no better than having none. Hence, twenty-two is rendered equal to zero!

4

WHEN DID ATOMIC AGE BEGIN?

One can answer that question with considerable precision. The atomic age dawned exactly at 25 minutes past 3 O'clock in the afternoon of 2nd December, 1942. Even the birthplace can be stated without any ambiguity. It happened at the squash courts beneath the West Stands of Stagg field in Chicago. The midwives were Italian Nobel laureate Enrico Fermi and his associates. On that day man first initiated a self-sustaining nuclear chain reaction, and controlled it. With that man ushered in a new era where the immense energy locked inside an atom was set free. Since then man has been exploiting it both for peaceful purposes as well as for building weapons of mass destruction.

The developments that led to this momentous event are themselves very interesting. Corbin Allardice and Edward R. Trapnell of the U.S. Atomic Energy Commission have provided us an eyewitness account of the episode.

The modern Italian explorer of the unknown was in Chicago that cold December day in 1942. An outsider looking into the squash court where Fermi was working would have been greeted by a strange sight. In the centre of the 10 m x 20 m room, shrouded on all but one side by a grey balloon-cloth envelope, was a pile of black bricks and wooden timbers, square at the bottom and a flattened sphere on top. Up to half of its height construction of this crude-appearing but complex pile, the name which has since been applied to all such devices, the standing joke among the scientists working on it was: 'If people could see what we're doing with a million and a half of their dollar, they'd

think we are crazy. If they knew why we were doing it, they'd be sure we are."

Three years before the December 2 experiment, it had been discovered that when an atom of uranium was bombarded by neutrons, it was sometimes split, or fissioned. Later still, it had been found that when an atom of uranium fissioned, additional neutrons were emitted and became available for further reaction with other uranium atoms. These facts implied the possibility of a chain reaction, similar in certain respects to the reaction which is the source of the sun's energy. The facts further indicated that if a sufficient quantity of uranium could be brought together under the proper conditions, a self-sustaining chain reaction could be maintained. The amount of uranium which makes it possible to maintain such a chain reaction under given conditions is

known as the 'critical mass', or more commonly, the 'critical size' of the particular pile.

Fermi and Walter Zinn and their associates were working to determine operationally possible designs of a uranium chain reactor. Among other things, they had to find a suitable moderating material to slow down the neutrons travelling at relatively fast velocities. Fermi who had mathematically demonstrated the feasibility of sustaining a chain reaction had realised that neutrons emerging out of a fission reaction would have to be slowed down in order to keep a chain reaction going without any hindrance. The energy of such slow neutrons would be close to thermal energy. Hence they were dubbed as thermal neutrons in contrast to those emitted by a uranium atom undergoing fission. The latter were described as fast neutrons.

A uranium atom that is split gives rise to an average of 2.3 neutrons. That would trigger another 2.3 uranium atoms to undergo fission. Each of these events would emit 2.3 neutrons and so on. Thus the chain reaction would continue in geometric fashion and can lead to an explosive situation. To keep such a chain reaction under control it was necessary to keep the reproductive ratio of neutrons at optimal levels. Fermi had carried out certain experiments in July 1941, to obtain measurements of the reproduction factor of neutrons, called "k", which was the key to the problem of a chain reaction. If this factor could be made sufficiently greater than 1, a controlled chain reaction could be made to take place in a mass of material of practical dimensions. If it were less than 1, no chain reaction could ensue.

One of the first things that had to be determined was how best to place the uranium in the reactor. Fermi and Leo Szilard suggested placing the uranium in a matrix of the moderating material, thus forming a cubical lattice of uranium. This placement appeared to offer the best opportunity for a neutron to encounter a uranium atom. Of all the materials which possessed the proper moderating

qualities, graphite was the only one which could be obtained in sufficient quantity of the desired degree of purity.

At Chicago, the work on sub-critical size piles was continued. By July, 1942, the measurements obtained from these experimental piles had gone far enough to permit a choice of design for a test pile of critical size. At that time, the dies for the pressing of the uranium oxides were designed by Zinn and then tailor-made to fit the criteria. It was a fateful step, since the entire construction of the pile depended upon the shape and size of the uranium pieces.

Construction of the main pile at Chicago started in November. The project gained momentum, with machining of the graphite blocks, pressing of the uranium oxide pellets, and the design of instruments. Fermi's two 'construction' crews, one under Zinn and the other under Herbert L. Anderson, worked almost around the clock,

Day after day the pile grew toward its final shape. And as the size of the pile increased, so did the nervous tension of the men working on it. Logically and scientifically they knew this pile would become self-sustaining. It had to. All the measurements indicated that it would. But still the demonstration had to be made. As the eagerly awaited moment drew nearer, the scientists gave greater and greater attention to details, the accuracy of measurements, and exactness of their construction work.

During the early afternoon of December 1, tests indicated that critical size was rapidly being approached. At 4 p.m., Zinn's group was relieved by the men working under Anderson. Shortly afterwards the last layer of graphite and uranium bricks was placed on the pile. Zinn, who remained, and Anderson made several measurements of the activity within the pile to determine whether it would become self-sustaining. Both had agreed, however, that should measurements indicate the reaction would become self-sustaining they should suspend further activity until Fermi and the rest of the group could be present. Consequently, the control rods were locked and further work was

postponed until the following day.

That night the word was passed to the men who had worked on the pile that the trial run was due the next morning. About 8.30 on the morning of Wednesday, December 2, the group began to assemble in the squash court.

At the north end of the squash court was a balcony about ten feet above the floor of the court. Fermi, Zinn, Anderson and Compton were grouped around instruments at the east end of the balcony. On the floor of the squash court, just beneath the balcony, stood George Weil, whose duty was to handle the final control rod. In the pile were three sets of control rods. One set was automatic and could be controlled from the balcony. Another was an emergency safety rod. Attached to one end of this rod was a rope running through the pile and weighted heavily on the opposite end. The rod was withdrawn from the pile and tied by another rope to the balcony. Hilberry was ready to cut this rope with an axe should something unexpected happen.

At 9.45 a.m., Fermi ordered the electrically operated control rods to be withdrawn. The man at the controls threw the switch to withdraw one set of control rods. A small motor whined. All eyes were glued to the lights which indicated the rods' positions. A quick calculation on the data supplied by the instruments made it clear that this was not enough. The reaction was not sustained. Cautiously, Fermi went on ordering withdrawal of more control rods and to increasing extents. The whole team went on conducting the cautious experiment without any success till well after midday.

Everyone was tired and hungry Fermi ordered a break and everyone adjourned for lunch. They reassembled at 2 O'clock and resumed work immediately. At 2.50 p.m. the control rod came out another foot. The counters nearly jammed, the pen headed off the graph paper. But this was not it. Counting ratios and the graphs scale had to be

changed. "Move it six inches," said Fermi at 3.20 p.m. Again the change—but again the levelling off. Five minutes later, Fermi called: Pull it out another foot." Weil withdrew the rod.

Fermi computed the rate of rise of the neutron counts over a minute period. He silently, grim-faced, ran through some calculations on his slide rule. In about a minute he again computed the rate of rise. If the rate was constant and remained so, he would know the reaction was self-sustaining. He repeated the procedure a few more times. Finally, he announced, "The reaction is self-sustaining."

"O.K., Zip in," called Fermi to Zinn, who controlled that rod. The time was 3.53 p.m. Abruptly, the counters slowed down, the pen slid down across the paper. It was all over.

Man had initiated a self-sustaining nuclear reaction, and then stopped it. He had released the energy of the atom's nucleus and controlled that energy.

Arthur Compton went to convey the good news by long distance telephone to James Conant who was waiting at Harvard.

"The Italian navigator has landed in the New World," said Compton.

"How were the natives?" asked Conant.

"Very friendly."

With those words mankind entered the atomic age.

5

WHEN DID HUMANS START WEARING CLOTHES?

"Apparel oft proclaims the man"! So said William Shakespeare. Be that as it may what Thomas Fuller opined is also true: "God makes and apparel shapes". The birthday suit of humans did not include any apparel. That is why Zoologist Desmond Morris calls human beings as Naked Apes; Naked, because unlike other primates *Homo sapiens* do not sport much fur on their body. That fur is probably helpful to those evolutionary kin of human species to protect themselves from vagaries of Nature. No such natural protection being available, humans had to use their brains and come up with the idea of wearing clothes.

That much is clear. But when exactly did this important transition in the human lifestyle take place? Anthropologists have long wondered when clothes began to appear. Since fur and fabrics do not fossilise, no evidence has been left, apart from some fabrics more than a few thousand years old.

Professor Mark Stoneking and colleagues at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany have now come to their rescue and provided a logical answer. They have put their genetic expertise to find a solution to this riddle. Their approach is focused on the subtle genetic differences between two independent parasites on the human body, the head louse, *Pediculus humanus capitis* and the body louse, *P. humanus corporis or P. h. humanus*. These human ectoparasites are genetically related. The body louse is an evolutionary offshoot of the head louse. Even so, they differ particularly in their habitat

on the host. The head lice live in the hair and scalp, while body lice feed on hairless parts of the body but lay their eggs only in clothes. It is thus obvious that body louse could not have started life as a separate species until there were clothes for it to survive and propagate. Thus, an indirect measure of the time when our ancestors first wore clothes can be obtained if we are able to figure out when body lice first appeared.

To determine that, Stoneking's team used a molecular clock approach—a dating method based on the rate that specific types of mutations accumulate in DNA. DNA is the molecule that contains, in a coded fashion, all the information that is necessary to construct the whole organism. This information is faithfully passed on from

one generation to the next. That is achieved by first replicating the information so that there are two identical copies. Though this process of copying is normally carried out with utmost attention to accuracy, some errors do creep in. Some of these result in modifying the coded message. In turn, this manifests in some members of the new generation sporting altered characteristics. When the number of such changed attributes reach a certain number that organism becomes notably different from the parent organism. A new species is said to have evolved.

Tracking these changes in the molecule that consists of the hereditary information makes it possible to find out when the two species separated from each other and started living as independent entities. Every cell in an organism contains the DNA molecule. However, it comes in two different varieties. One of these is present in the nucleus of the cell. The nuclear DNA is responsible for determining almost all of the hereditary characteristics of an organism. This DNA is inherited from both the parents. There is another variety of DNA that is found in one of the cellular organelles, the mitochondria. The mitochondrial DNA is inherited only from the mother. The father has no role in it.

There is yet another difference between the nuclear DNA and the mitochondrial DNA. Changes in the nuclear DNA arise out of errors during the copying process in addition to the spontaneous changes that nature throws in from time to time. Changes in the mitochondrial DNA are only spontaneous. The molecular clock that allows us to determine the age of any species looks only at these changes or mutations in the mitochondrial DNA. Specifically, the age of any particular species is determined by noting the number of differences between its own mitochondrial DNA and that of a second related species.

Since mitochondrial DNA isn't subject to genetic changes during reproduction, any changes that are manifest are the result of mutations, spontaneous changes induced by Nature in the sequence of bases that constitute the DNA chain. By

establishing a statistical rate at which mitochondrial mutations occur, scientists can use the number of differences between the two species to calculate how long ago they diverged and separated from each other.

The team examined differences between parts of the mitochondrial DNA of body lice and head lice. In addition, because human beings and chimpanzees went their separate ways 5.5 million years ago, the team compared the human louse sequences with the sequences of chimpanzee lice. The latter comparison made it possible to calibrate the rate of change in the genomes of the lice. Assuming that mutations occur at a given rate, Stoneking's team came to the estimate that "body lice originated not more than about 72,000 to 42,000 years ago." The date fits with fossil and archaeological evidence about various tools invented by humans. The only tools that can be definitely associated with clothing, such as needles, are about 40,000 years old.

The genetic results also indicate greater diversity in African than non-African lice, suggesting an African origin of human lice which matches other data of human origins.

So if you were asked, 'When did humans catch the fashion bug?', you can confidently state that it was around 50,000 years ago.

6

WHEN DID LIFE ORIGINATE ON EARTH?

Once upon a time there lived one James Ussher, Archbishop of Armagh, Primate of All Ireland, and Vice-Chancellor of Trinity College in Dublin. After a detailed study of the story of genesis as depicted in the Bible he declared that the world in all its features including the diverse forms of all living things was created in a space of just six days beginning at 9 a.m. on October 26, 4004 BC.

Although Ussher brought stunning precision to his chronology, Christians for centuries had assumed a history roughly corresponding to his. The Bible itself provides all the information necessary to conclude that Creation occurred less than 5,000 years before the birth of Christ. Shakespeare, in *As You Like It*, has his character Rosalind say, "The poor world is almost six thousand years old." Martin Luther, the great reformer, with his penchant for the round number, opted for 4000 BC as a date for creation. Astronomer Johannes Kepler concluded that 3992 BC was the probable date.

Once upon a time, such legends were common in mythological literature. Different civilizations have faith in different stories. According to a Hindu belief, life emerged through the navel of Lord Vishnu as he reposed in the tranquil ocean of milk, the *kshirsagar*. A lotus leaf bloomed out of the navel on which the first child made its appearance. Another fairy tale credits *Samudramanthan*, the churning of the ocean carried out by the *Devas* or the Gods and the *Asuras* or the demons, giving birth to living matter.

But these were mere fictitious tales. If true, they would

imply that living beings were generated out of thin air. However, it was shown very convincingly by Louis Pasteur that spontaneous generation, which is the basis of all these legends, is just not possible. A living organism alone can give birth to another. Moreover, the world is at least 4.5 billion years old. There is a large body of evidence to support this contention. The oldest rocks found on Earth are themselves 3.5 billion years old. So the world cannot be merely 6000 years old as envisaged by Archbishop James Ussher. Even if we assume that Ussher was referring to emergence of living organisms on this planet and not the birth of the planet itself, very reliable evidence obtained from fossils proves him wrong. Fossils of animals as well as plants that are at least hundreds of millions of years old have been discovered in different parts of the world. So Ussher's or that of other notable individuals' answer to the question, 'When did life originate on earth?', cannot be accepted.

Yet one small detail of all these stories is true. According to all of them once upon a time there was no life on this Earth. Then how did it emerge? Was it a miracle performed by some fairy? Did she say 'Hey presto, let there be life' and it was there even as she finished waving her magic wand?

That can happen only in fairy tales. The story of creation of life on this planet, indeed the only place in the universe where life is known to exist as of now, runs quite differently. Still, one conundrum remains to be resolved before one can start unfolding that fascinating saga and seek answers to the question that confronts us.

If one goes by what Louis Pasteur had to say, then it is not possible for a living being to emerge from thin air. That organism has to take birth from its living parents. At the same time, it is also true that once upon a time the earth was barren. There was not a living soul anywhere to be found. How did the first living organism then come into being? What are then the origins of life? How did things go

from non-living to living? From something that could not reproduce to something that could? Either one has to accept that Pasteur was wrong or one has to come to the equally impossible scenario that life had always existed on the Earth, right from its beginning. It is a very nice conundrum, isn't it? Heads you win and tails also you win!

Not really. You have pictured such a situation because whenever one talks of life one thinks in terms of life as one sees it today. When one goes out and walks in the woods or on a beach, the most conspicuous forms of life one will see are plants and animals, and certainly there's a huge diversity of those types of organisms, perhaps 10 million animal species and several hundred thousand plant species. But these are evolutionary latecomers. The history of animals recorded from fossils is really only the last 15 per cent or so of the recorded history of life on this planet. The deeper history of life and the greater diversity of life on this planet is that of microorganisms—bacteria, protozoa, algae. One way to put it is that animals might be evolution's icing, but bacteria are really the cake.

It's pretty clear that all the organisms living today, even the simplest ones, are far removed from some initial life form of four billion years ago or so. So one has to imagine that the first forms of life would have been much, much simpler than anything that we see around us. But they must have had that fundamental property of being able to grow and reproduce and repair themselves. Also they should be capable of undergoing transformation in a manner that Darwin had described.

So it might be that the earliest things that actually fit that definition were little strands of molecules; something that could catalyze some chemical reactions, something that had the blueprint for their own reproduction.

For thousands of years humans have wondered about the beautiful lights in the dark night sky. Over time astronomers began to understand what they were seeing. Today we know the universe contains more galaxies than

there are people on Earth. And each galaxy contains hundreds of billions of stars. Some of the stars are so enormous that it would take years for a spacecraft just to get from one side to the other. Some stars are no wider than a small city. Our Sun is about midway between these extremes.

The Sun is a star still in its youth. Stars do not exist forever. Like people, they are born and they die. Astronomers have discovered that the entire Universe too has not existed forever. About 15 billion years ago, an enormous explosion called the "Big Bang" created an expanding bubble of energy. In the first few minutes after the Big Bang, with temperatures of at least 18,000,000 degrees, nuclear fusion reactions converted part of the hydrogen into helium. After half million years, radiation and matter separated. Galaxies then began to form from the gas. Later, stars were born within the galaxies. One of those stars was the Sun. Astronomers estimate the sun was born 4 ½ billion years ago. Earth and the other planets of the solar system were formed along with the Sun from leftover material.

The birth and death of stars is the process that creates the chemical elements that make up everything in our world-including ourselves. Stars operate like factories, creating these elements in the furnaces of their own contractions. The solar system consists of the Sun and those bodies, such as planets, satellites, asteroids, and comets, which are trapped by the Sun's gravity into a variety of orbits around it.

The Milky Way Galaxy had been in existence for billions of years when the Sun was born. Millions of stars were born and later died. In the gaseous swirls of the Galaxy, they left a rich "soup" of chemical elements in the form of gases and dust. These stars provided the raw materials for future stars and planets. A cloud of gas and dust began to contract, possibly triggered by the explosive death of a nearby star. As it spun, its core became denser and heated

up until it reached nuclear ignition point. The Sun was born.

The new Sun did not use up all of the available material in the rolling gas cloud from which it was formed. While the Sun began to shine with fusion reactions, particles in the cloud around it began to coalesce to form other much smaller bodies. These were the planets. Most scientists think the planets originated in the same gas and dust cloud from which the Sun condensed.

The nine planets (now eight, with Pluto degraded to the status of a sub-planet by scientists in 2006), of which the Earth is one; orbit the Sun at different speeds. Compared to the Sun, the planets are tiny. All together, they have only one-thousandth of the mass of their parent star, the Sun. Just as the planets orbit around the Sun, the moons or satellites of the Solar System rotate around their parent planets.

As the newborn Earth consolidated, its internal heat became so fierce that it caused the solids to melt. The heavier elements in the planet's make-up were drawn down into the centre. Lighter elements, including gases, moved to the surface. This surface began to form a crust. Above it, an atmosphere began to form from the gases ejected through the cooling crust by the pressures within. They included carbon dioxide, nitrogen and water vapour. The Earth's gravitational pull held onto the atmosphere being created from the volcanic emissions. Volcanic steam condensed to form thick clouds that blanketed the planet. The surface continued to cool. Eventually, the clouds began to pour down rain. It was a rain that lasted for millions of years.

The rains created the first oceans. By the time the Earth's surface had cooled enough to interrupt the almost endless cycle of evaporation and condensation, the planet had begun to demonstrate its unique characteristic. It is the only body in the Solar System with a surface covered largely by water. This cover of water had a significant affect on the atmosphere. It dissolved some of the gaseous elements in

the air, making the atmosphere thinner. Composed mainly of carbon dioxide and nitrogen, it also included ammonia, carbon monoxide, hydrogen and methane. There was no significant amount of oxygen yet.

In early 1950's, the American Nobel laureate Harold Urey suggested that the Earth had a reducing atmosphere, since all of the outer planets in our solar system—Jupiter, Saturn, Uranus and Neptune—have this kind of atmosphere. A reducing atmosphere contains methane, ammonia, hydrogen and water. Several scientists including the Russian Aleksandr Oparin and Harold Urey himself had argued that such an atmosphere devoid of oxygen was necessary for emergence of life on Earth. So Urey's student Stanley Miller tried to conduct an experiment to test this hypothesis. He was a young graduate student fired with enthusiasm. He, therefore, embarked upon a fairy tale of his own. He created in the laboratory a model of the infant Earth.

He took a big five litre glass flask. He filled it with water to simulate the ocean. The water was kept boiling because the Earth in those ancient times was still rather hot. The steam thus generated was passed through a tube into another big flask that was kept at a higher level. The second flask contained a mixture of gases. It included methane, ammonia and hydrogen. This was the sky that covered the Earth. A pair of electrodes were inserted into the upper flask. The whole system was then subjected to certain natural traumas such as ultraviolet radiation and the high voltage discharges typical of electrical storms and lightning bolts. The energy needed to get a chemical reaction going was thus provided. All in all the total set up replicated conditions that prevailed at the dawn of Earth.

The bottom of the flask containing artificial atmosphere was connected to a condenser, so that the products formed in that gaseous chamber were washed down back into the artificial ocean below. You could call it an attempt to recreate the rains that showered down on the virgin Earth.

The closed system represented the early hydrosphere in

which the Earth was ensconced. Miller kept the cauldrons boiling for a full week. Anyone watching the experiment would surely have experienced an eerie feeling with the ocean madly boiling, the lightning discharge furiously flashing and the rain drops continuously falling into the sea.

But the results were purely magical. They were far beyond the initial expectations. The lower flask which had contained only pure water at the beginning of the experiment, barely a week earlier, was now full of organic molecules like urea, formic acid, acetic acid, and propionic acid. More importantly, a number of amino acids like glycine, alanine, aspartic acid and glutamic acid were present.

All of these molecules are essential to life. Formic acid, acetic acid and propionic acid are simple forms of the constituents of fats. Amino acids link together to form proteins. Urea, rich in nitrogen, plays an important role in many biological processes. Miller had succeeded in showing how life could emerge from inanimate inorganic molecules. Thomas Huxley was vindicated. He had said that there was no fundamental difference between a living organism and lifeless matter. Life crucially depended on certain molecules which themselves were inanimate. Yet, when they came together and organised themselves in a specific manner, they gave rise to rudiments of a living organism. The conundrum was thus resolved without violating Pasteur's edict.

This enormous finding inspired a multitude of further experiments.

In 1961, Juan Oro found that amino acids could be made from hydrogen cyanide (HCN) and ammonia in an aqueous solution. He also found that his experiment produced an amazing amount of the nucleotide base, adenine. Adenine is of tremendous biological significance as an organic compound because it is one of the four bases in RNA and DNA. It is also a component of adenosine

triphosphate, or ATP, which is a major energy releasing molecule in cells. Experiments conducted later showed that the other RNA and DNA bases could be obtained through chemical reactions between simple inorganic molecules under a reducing atmosphere.

There is some dispute over the composition of primitive atmosphere. Urey had argued that in the absence of reducing atmosphere the organic compounds required for life would not emerge. If they are not then made on Earth, they would have to be brought in from elsewhere, on comets, meteorites or dust.

In 1969 a carbonaceous meteorite fell in Murchison, Australia. It turned out the meteorite had high concentrations of amino acids, about 100 parts per million. They were the same kind that Miller had obtained in his experiments. This discovery made it plausible that similar processes could have happened on primitive Earth, on an asteroid, or for that matter, anywhere else where proper conditions existed.

That is why some people, notably Fred Hoyle, have contended that life was seeded on Earth from outer space. This concept is known as the theory of panspermia. It may be that life came to Earth from another planet. If so, it still doesn't answer the question of where life started and how. You only transfer the problem of the Earth to the rest of the solar system and possibly beyond. That is the reason that it is now commonly accepted that life originated on Earth in a way that Miller has shown.

Still, whether it originated right here on Earth or was seeded from elsewhere, this basic question remains. When did this happen? When did the barren Earth start teeming with life? When did life originate on Earth? By all reckoning, events similar to those described by Miller took place some 3.6 billion years ago.

7

WHEN DID THE NIAGARA FREEZE?

The Niagara Falls is one of major natural wonders of the world. Its statistics are mind boggling. It spans two large countries. The international border between Canada to the north and the United States to the south runs midway through the Falls.

These are actually three separate Falls that collectively are called by this name. One of these lies totally on the American territory. Obviously this is known as the ***American Falls***. It extends over a length of about 350 metres and falls down from a height of about 60 metres. The smallest among the three is the ***Bridal Veil Falls***. It is a kind of bridging fall which joins the Canadian wing to the American part. The Horseshoe or the ***Canadian Falls*** is the biggest in terms of its total width. It covers a distance of almost 900 metres. Together the total amount of water that jumps over is estimated to be about 750,000 American gallons that is about 4 million litres per second.

Yet, this large body of water has been taking this plunge only for the last 12,000 years, a mere microsecond on the geological time scale. That is because the Niagara river is one of the youngest rivers. The Niagara escarpment, nonetheless, is much older. It was created, according to geologists, during the retreat of the last Ice Age. The glaciers during that ice age had pressed down on the land and dumped a great deal of sediment. The process of erosion had commenced then and had been going on for a long time. The mighty river now plunges over a cliff of dolostone and shale.

The Niagara river owes its origin to the four great lakes in northern United States, Lake Michigan, Lake Huron, Lake Superior and Lake Eerie. A full one-fifth of the total fresh water in the world is stored in these lakes. Their outflow empties into the Niagara river. All that water then flows over the cliffs, giving rise to this awesome spectacle.

One would then wonder whether such a large body of water flowing with a significant speed would ever freeze. The gut feeling would be, no, it would never get frozen. Yet the seemingly impossible appeared to have happened. Though what actually happened may not qualify to be called freezing of the Falls in the strictest sense, the Falls did stop for some time in 1848.

The tremendous volume of water never stops flowing. Man has tried his best to accomplish that. Yet with all his technological prowess he has failed in that mission. The area near the Falls on both the Canadian and the American sides experiences severe winter with temperatures plummeting to 35 degrees below zero. Even at those low temperatures the Falls continue unhindered. However, the falling water and mist create ice formations along the banks of the Falls and the river. All the balustrades and the poles in the vicinity sport enchanting ice sculptures during this period.

Just as the total volume of water is unimaginable so is the extent of ice formation. Mounds of ice as thick as 15 metres are not uncommon. During very cold winters, that last for a long time, the ice stretches completely across the river. Thus it forms what is known as the ice bridge. This bridge can extend for several kilometers. Until 1912 visitors were allowed to walk on the bridge. That allowed the enterprising tourists to watch the Falls from below. But that year the bridge suddenly gave way and three tourists lost their lives. Ever since, that attraction has closed down. The ice bridge, nonetheless, continues to form during those harshest of winters. People can then watch it from a safe distance.

Sometime the lakes feeding this river freeze. Since they are relatively stagnant, their freezing occurs easily. In particular, Lake Eerie freezes more often and also to a larger extent. This creates icebergs to flow out to the river. These monsters do affect the flow of river and create massive obstacles.

On March 29, 1848 people witnessed the unthinkable. The Falls stopped completely. Of course, they were not frozen, but the river upstream was blocked by an ice jam and had stopped flowing. Naturally, there was no water to dive down the cliff. People could actually walk on the river bed and collect some very valuable artifacts. This state lasted for several hours. Only after the jam had cleared up naturally, the flow of the river resumed. The Falls were restored to their majestic self. The eerie silence that had descended on the spot gave way. The deafening roar could be heard once again to the satisfaction of almost every one.

To avoid repetition of this catastrophic event, an 'ice boom' is installed in Lake Eerie every year. It is actually a 3.2 km long floating chain of steel. It is strung across the river span extending from Buffalo in the US to Fort Eerie in Canada. It is set in place in December and continues to remain in position over the next three to four months. It helps prevent ice formation in the lake. The iceberg formation is reduced. The river does not get choked.

So when did the Niagara Falls freeze? Well, it has never been frozen. But the Falls did stop for several hours late in the winter of the year 1848.

8

WHEN DID TIME BEGIN?

Time is not a concrete entity like any of those that we can measure. Nor is it a continuing event that had unfolded once and perhaps will wind down in the future. Such happenings have a beginning and one can determine that. Time, in striking contrast, is rather a psychological sensation.

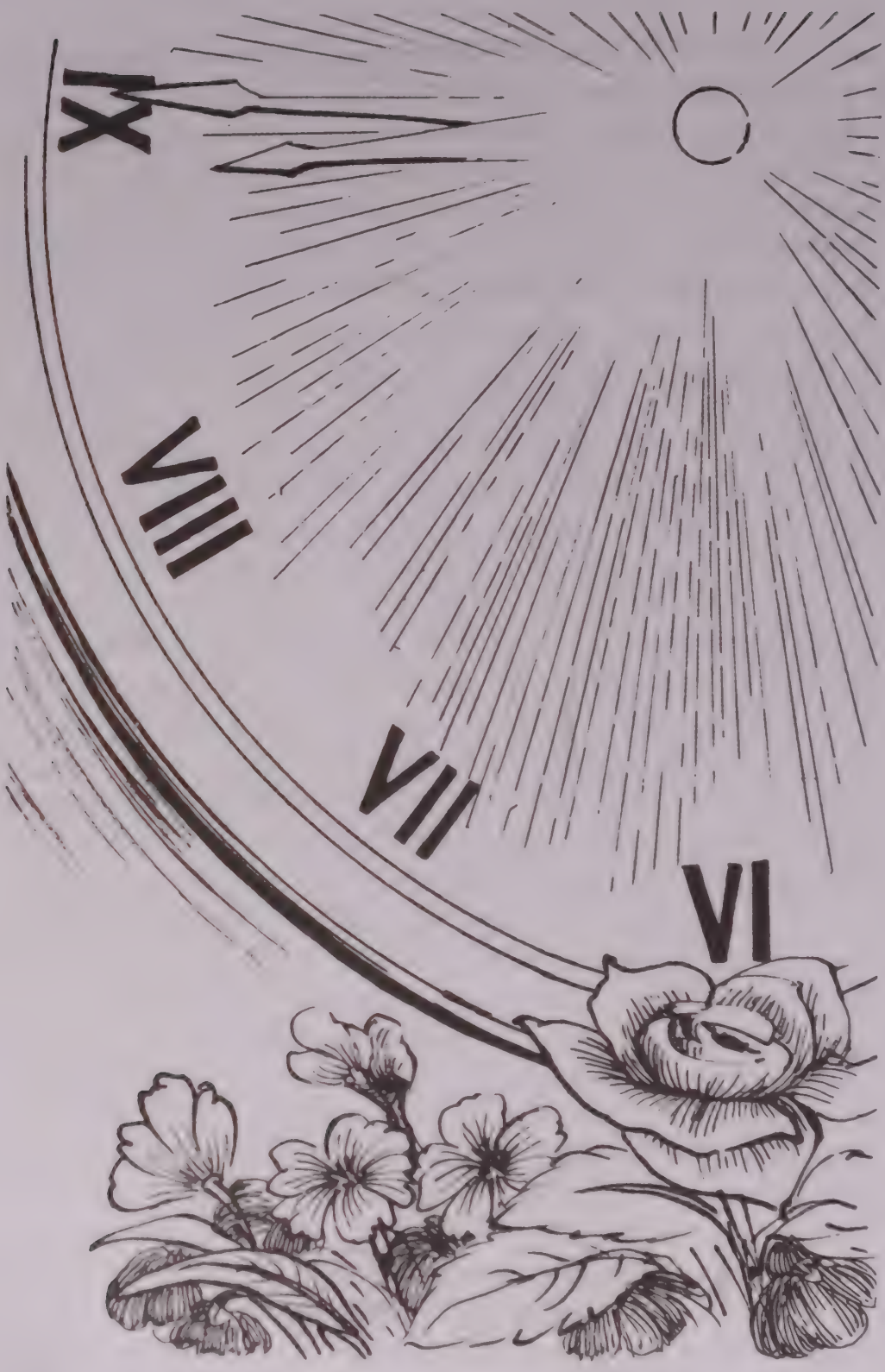
We become conscious of the fact that there is an interval between two events that we can witness or experience. The tree comes alive with new foliage. After some interval, it blossoms with colourful flowers. Later still, it bears delicious fruit. These are discrete real events with some interval between them. We feel pangs of hunger. To quell those we eat something. But the hunger is not suppressed for good. After some interval we are once again famished. The Sun rises with its brilliant light shining on the earth. After a decent interval it disappears letting darkness rule over *terra firma*. The heat of the Sun, while it is shining, raises the temperature of the environment. Our bodies start sweating. We start craving for water. Some interval passes and the sky starts to darken. Lightning flashes across the skies accompanied by frightening thunder. Rains lash the earth. The streams and rivers start flowing in full swing. They even burst their banks flooding the surrounding area. After another decent interval the skies open up. The Sun starts shining in all its glory. But this time around it does not bite, for the environment is cooler. As the Sun starts taking our leave we start shivering. After yet another interval we once again experience unbearable heat. We want to shed our clothes.

Natural occurrences like these continue in their eternal cycles. Events come a full circle only to begin another cycle making us appreciate the existence of intervening intervals.

Time is this cognitive awareness that events do not occur as a continuous stream, that there are distinct intervals between them. We also realise that the lengths of intervals between different events are different. They are not always the same. Also, depending on the circumstances our comprehension of the extent of these intervals can vary.

Even a short interval of hard work under a scorching Sun gives an impression of the interval stretching endlessly. However, relaxing thereafter in a festive atmosphere to the accompaniment of song and dance makes one feel that the night has passed all too quickly. One can go on for ever splashing around in the refreshing waters of the river to get away from the noontime heat without feeling that a long interval has passed. On the other hand, during cooler season, when the same water turns ice cold, dunking inside even fleetingly gives an impression of being there for an unreasonably long interval. Even the same length of interval under identical set of conditions appears to be dissimilar to different people depending upon their disposition.

If the same interval thus appeared to be widely different to different individuals, it can create a lot of confusion and problems. If these personal cognitions have to be converted into something useful for a tribe or the society of which he or she is a member, then some way of ensuring that everyone would feel the interval to be of the same length had to be evolved. The concept of time thus came into being principally to fulfill this requirement. That inevitably led to setting up means of measuring the interval of time. The individual psychological sensation was thus ensconced into a public frame of reference for the benefit of the society at large. That is the reason time, or rather an interval of time, can be measured. This is in spite of the fact that time is not a concrete entity; nor does it have any specific shape or size or colour. It does not occupy any volume; nor does it possess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any mass and hence weight. Yet it can be measured distinctly.

Human awareness of time is simply the ability to distinguish which of any two events is earlier and which later, combined with a consciousness of an instantaneous present that is continually being transformed into a remembered past as it is replaced with an anticipated future. From these common human experiences evolved the view that time has an independent existence apart from physical reality.

The concept of time was thus firmly established to convert the cognitive feeling of intervals into a measurable entity. This is one item that can be evaluated even though it does not possess the usual features of a discrete entity like shape, size, volume or weight. It can be quantified even though it cannot be seen or handled. That is the beauty of time.

One can, therefore, consider the establishment of this concept in human psyche as the beginning of time. If that line of thinking is accepted then time began way back when man first took notice of various repetitive natural phenomena occurring all around him. Since the emergence of modern man is considered to have taken place around 100,000 years ago, time can be said to have begun sometime soon thereafter.

However, if one were to be exact and very truthful, that dating would only mark the beginning of the concept of time and man's awareness of its existence. Can one really say then that that marks the beginning of time *per se*?

Time is the measure of interval between two events. So the very first event that occurred anywhere can be a very good marker to keep tab of time. Emergence of this universe would then be the very first such event. Nothing existed before that. That would then be the beginning of time. According to that thought time began some 12 million years ago when the Big Bang brought this universe into being.

Strictly speaking though time has a mystic surreal

character. The best description of time is the one given by Albert Einstein. He said that, "Space and time are but points of reference with respect to which we think. They are not fundamental properties that constitute the foundation of our life, of our existence. "

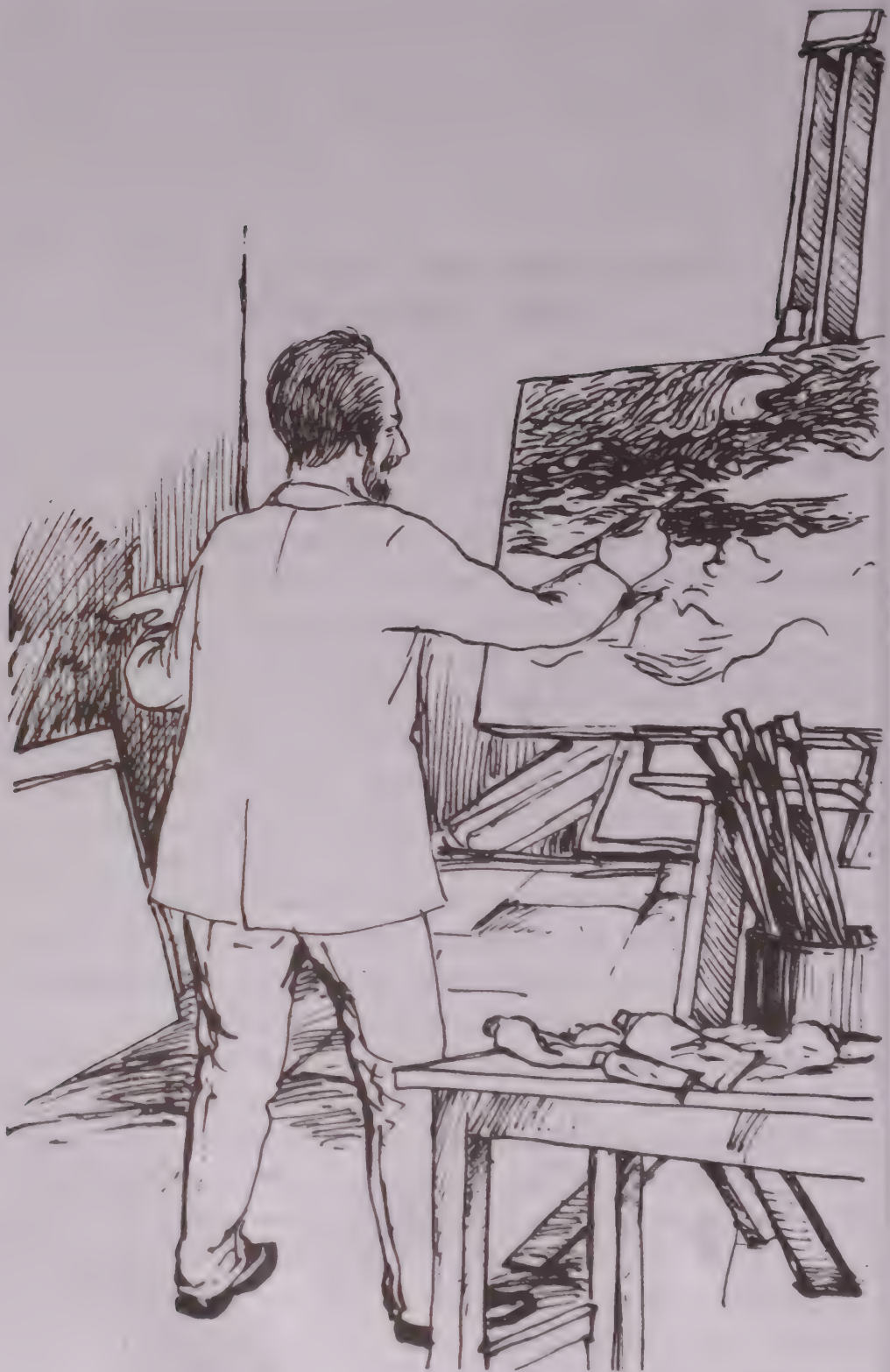
Time, thus, has no beginning nor end. It flows eternally from the past to the future.

9

WHEN DID VAN GOGH PAINT 'THE MOONRISE'?

Is this the right question to ask? After seeing a work of art one may ask who is the concerned artist. It may be possible to find a credible answer to that question from the style deployed in that painting. Every renowned artist has a characteristic style of his own that betrays his hand. If it is a portrait it may even be possible to tell who the person portrayed is. Looking at the world famous Mona Lisa people have often asked who is the model whose enigmatic smile has been immortalised by Leonardo da Vinci. A landscape might give rise to the question: Where was it painted? From some of the tell-tale clues found in that canvass it may be possible to zero in on to the exact location. But can one honestly ask when a particular canvass was painted? And expect that the painting itself would provide enough evidence for a truthful answer to that question? But this is precisely what a team of astronomers have done.

Vincent van Gogh, the Dutch Master was a remarkable painter. His life was equally picturesque, inspiring Irving Stone to write the famous biographical novel ***Lust for Life***. Later still the novel was made into a very enchanting film. His paintings command very high prices today. Yet during his lifetime he was not able to sell even a single one and was forced to eke out a living on the generosity of his brother Theo. Vincent also went through several periods of acute depression during one of which he was driven to cut off his own ear. Even so, his brushstrokes are unique and



have carved for themselves a very special place in the history of art.

Though several of his paintings like the 'Sunflowers', 'Wheatfields and the Crow' have become famous; 'The Moonrise' has been shrouded in mystery. It looks like a sunset but is not because it is clearly titled as 'The Moonrise'. Moreover, unlike many of his other works, the actual date on which he painted this, has been unknown. Naturally it has attracted attention of art historians and scientists alike. Both have wanted to find out when exactly did Vincent paint this particular canvass.

There are some clues to be found in the letters that he wrote to Theo. Vincent spent a rather disturbed period of his troubled life at a monastery in the south of France. This was during the summer months of 1889. He died soon thereafter. In one of the letters, dating back to this period,Vincent mentions this particular painting. Thus the search could be narrowed down to a period of five months in that year.

Still the exact date was not known. But using old-fashioned detective work and modern astronomical tools, a team of scientists have solved one of the most intriguing mysteries in art history, the precise moment that Vincent van Gogh has frozen forever in this painting.

Donald Olson, Russell Doescher and Marilynn Olson of Southwest Texas State University dug into the mystery. They pieced together a variety of clues: notes from the artist, lunar table calculations and personal excursions to identify and analyse the location in France depicted in the work. The work itself, painted near a monastery in Saint-Rémy-de-Provence in southern France, offered enough hints to figure out where van Gogh had set up his easel: an unusual double house beside a hill, an intersecting wall and clumps of harvested wheat.

So they went to the Saint-Paul monastery in Saint-Rémy, France, to look for the scene. The mountains and an overhanging cliff were evident. Trees had overgrown the

area, but they eventually found the house that's depicted in the work. Everything was picture perfect. All the details shown in the painting could be found there. The key was in the moon, which was hidden behind the cliff. Looking at the house the team could find that massif in the right place. It also became clear to them that it was indeed the moonrise and not the sunset. The latter would have been in the west and hence in the opposite direction.

Van Gogh was known to have painted by direct observation, not memory. And a peculiar ridge that obscures a portion of the rising moon serves as the de facto smoking gun to calculate the moment recorded in the painting. One night before or after and it would not align with the cliff.

Using lunar tables and astronomy software, they then calculated the time and dates at which a rising full Moon would appear above the horizon at that spot. There were two possible candidates, 16 May and 13 July, 1889. The final clue lies in the harvested wheat in the painting. So it could not have been May. Vincent van Gogh has two other paintings of that field in May, and they're lush green. So the date must be 13 July. Also, the painting must have been conceived at 9:08 p.m. because that was the time that the rising moon that day came to occupy the position behind the cliff depicted in the painting.

So now the art historians need not shrug their shoulders if asked that intriguing question, When did van Gogh paint 'The Moonrise'? They can say with a degree of confidence that it was the night of 13 July 1889. In fact they did say this by organising a special festival at the very location on 13 July 2004. Those participating in that fest could see for themselves what van Gogh had been captivated by on that particular night.

10

WHEN DO BIRDS MIGRATE?

Birds like many other animal species are creatures of habitat. Each one finds out a territory that is best for its living and perpetuating its breed and brood. The criterion for selection are availability of food and water, comfortable climate and cosy sites for building nests. Once such an environment is found birds would not normally want to leave it. Food, water, protective cover, and a sheltered place to nest and breed are basic to a bird's survival. But changing seasons can transform a comfortable environment into an unlivable one—the food and water supply can dwindle or disappear, plant cover can vanish, and competition with other animals can increase.

Most wild animals face the problem of occupying a habitat that is suitable for only a portion of the year. In particular animals, birds included, normally living in habitats that experience extreme weather conditions find it difficult to carry on in the normal lifestyle when inclement weather prevails. This happens more in northern latitudes in the northern hemisphere and southern latitudes in the southern hemisphere. Southern latitudes, in the northern hemisphere, provide considerably more congenial winter weather.

Fortunately, however, nature has provided methods for coping with the situation. One method, known as hibernation, involves entering a dormant state during the winter season. The other method, known as migration, involves escaping the area entirely. Because of the powers of flight, most birds adapt to seasonal changes in the

environment by migrating; only a few birds species, such as the *common poorwill*, hibernate. Insectivores (insect eaters) and frugivores (fruit eaters) can find food, by moving south, that they could never find in a harsh winter environment.

Certainly not all, but many of the birds that remain north in the winter eat seeds which do remain available in winter.

In North America, where the winters can be very severe, the ratio of migratory to non-migratory birds varies greatly from region to region. In high arctic regions, northern Alaska, northern Canada, and Greenland, where many shorebirds and water fowl nest, the entire population often consists of migratory birds who are only there during the summers. In the forest and open country of eastern United States, over 80 per cent of the nesting land birds are migratory, spending the winter in more hospitable southern climates. There is a similar high percentage of south-migrating birds in inland areas of the West. However, in areas where the climate is more equable, like the Pacific Coast, more species are non-migratory. In tropical regions at least 80 per cent of the birds are non-migratory.

Some migration schedules do not always closely follow seasonal changes in the weather. For example, since the vegetative food supply of nomadic species such as the *crossbills*, *redpolls*, and *pine grosbeaks*, fluctuates in abundance from year to year, these birds migrate in some winters and not in others. In contrast, insect-eating birds such as *warblers*, *vireos*, and *flycatchers* that live in the far north have no choice but to migrate from their summer habitats, since their food supply always disappears from sight in winter. Their migration, therefore, tends to involve long distances and regular timing.

Birds tend to commence migration in large numbers only when they have a favourable tail wind. Once started, however, only very bad weather will stop them. Many birds fly high when migrating because of prevailing winds at higher altitudes and also because the cold at these altitudes helps them to disperse all the heat that is generated by their flight muscles. Many species of *wildfowl* fly at 6000 m and some have been observed flying at 8000 m, at a speed of 150 km per hour with the ambient temperature being –48 degrees C.

Not all birds from a summer breeding site spend their winters at the same area. What happens, come autumn, if a male bird meets a female bird in the breeding grounds who has a different site for spending the winter? Whose site do they go to now that they are a pair? In many species the pair bond breaks up at the end of the breeding season, but some like swans mate for life. In the case of the *Bewick's Swan*, the male decides where to fly for the winter and the female follows him. However, the female decides when it is time to travel back to the original site for another year's breeding.

The reverse scenario is when birds with different breeding sites come to the same area during winter. If pairing commences on the winter vacation ground, whose breeding ground do they return to? The answer may be different for different species.

Timing of migration is a mix of internal stimulus which results in a feeding binge to put on fat to survive the journey and then the tendency to aggregate into flocks. Once the pre-migration flock is gathered, the feeding continues while the birds wait for suitable weather conditions. Thus while the internal clock of the birds probably releases the hormonal trigger at a fairly accurate date each year, the availability of food and the presiding weather conditions decide when the migration starts and hence when we see the first spring migrants arrive and the last autumn ones leave.

Migratory routes are not fixed eternally and in some species part of the population follows one route and part another. Also, some birds travel south by a different route to the one they use to travel north. Some migrants fly very long distances. Some *arctic terns* fly 18,000 km each way. Other birds fly lesser distances.

Northern summers have very long days that provide many hours for gathering food. Tropical days are only 12 hours long. Days in the north may reach 16 hours or more. It takes a great effort and a lot of time to gather enough food to feed three or four young ones who will increase to

50 times their hatching weight in just 13 days. Northward migration expands the available nesting and food gathering area of the world. Many migrating species occupy totally different areas while some merely expand their range to the north in summer, with some individuals finding nesting space to the north and others remaining stationary. Eggs and nestlings cannot fly. Parents must be sure there is sufficient territory around the nest to support their voracious family.

"I got rhythm; I got rhythm; I got rhythm; Who could ask for anything more?" That's how the song goes and that's how the birds go. Phonology is the study of biological rhythms. Periodic activity such as flowering, reproduction, and migration, all fall within this class of study. Words like circadian (daily), menstrual (monthly), circannual (annually) are used to describe these phenomena. Much of migration activity in birds is controlled by an internal clock operating on a circannual rhythm. Each year, at a certain time, their biological clocks signal that it's time to fly northward to breed.

Another factor is what is known as the photoperiod or periods of light. This actually refers to the ratio of day length to night length. Photoperiodicity may affect migration in some cases when the birds are in the temperate zones, where these ratios change. In the tropics, however, photoperiods don't have much effect. Days and nights are always 12 hours long on the equator. The triggers for migration are actually a complex combination of things.

So when do the birds migrate? They do so when their natural breeding habitat turns uninhabitable or even hostile. Since seasonal variations at any particular spot do not always occur at a fixed time, year in and year out, the precise time at which birds commence migrating also varies a little over years.

11

WHEN DO BIRDS SING?

Do they really sing? It is true that almost all the birds do produce some vocal sound or the other. While some of these sounds are quite harsh, others are indeed melodious. No doubt, the latter make a very pleasant hearing. In particular small birds like Robins and Finches do chirp in a harmonious fashion. But can one label them as 'songs'?

Sebastian Dregnaucourt of the City University of New York is convinced that the vocal utterances of many a bird species would qualify as music. He has a reason to be so assertive. He spent three years recording everything that some 40 birds that he was experimenting with gave voice to. He ended up with some 40 million musical syllables of data. Detailed analysis of these recordings made it clear that these sounds can be divided into two categories. Some of these are songs, which usually are long and complex. Others can be classified as calls, which usually are short and simple. There is thus no doubt anymore that birds do sing. That, nonetheless, does not yet tell us when they sing.

The vocal ability of birds has inspired poets and musicians, from Chaucer to Wordsworth, from Handel to Respighi. Birdsong can be a natural phenomenon of intense beauty. But our enjoyment is incidental to the main purpose, which is one bird communicating with others. Birds became the world's master musicians in order to convey to potential mates, rivals and predators, all the important things they have to say, from "Clear off!" to "Come on!"

Incidentally, their songs have been shaped by their environment, just as the Bhangra musician of Punjab

delivers a different 'tune' to the vocal exponent of Carnatic music in the temples of South India. The musical detail would have impressed the great composers. The Nightingale, for example, holds up to 300 different love

songs in its repertoire. The canary may take 30 mini-breaths a second to replenish its air supply. The Cowbird uses 40 different notes, some so high that we can't even hear them. The Chaffinch may sing its song half a million times in a season.

Indeed, British musician David Hindley slowed bird song down and discovered parallels between the Skylark's blizzard of notes and Beethoven's Fifth Symphony; between the Woodlark's mind-numbingly complex song and J.S. Bach's 48 Preludes and Fugues. It changes its tune according to the rules of classical sonata form. Someone ought to find out similar parallels between bird song and different ragas that constitute the foundation of Indian classical music.

Song allows the bird to 'speak' better than any other family of creatures. It is the perfect medium for communicating over long distances, or when it is hard to see the singer, and the audience, for example, at night or in dense vegetation.

For the most part, it is the males that 'sing' a consistently repeated pattern of tones. But in a few species, the female also occasionally breaks into song.

The vocal skill of birds derives from the unusual structure of their powerful vocal equipment. The syrinx is the sound-producing organ in birds. It is the equivalent of the human sound box. The syrinx contains membranes which vibrate and generate sound waves when air from the lungs is passed over them. The muscles of the syrinx control the details of song production; birds with more elaborate system of vocal muscles produce more complex songs.

But unlike our soundbox, which is situated at the top of the trachea, the bird's syrinx is set much lower down, at the junction of the two bronchi, or air tubes, leading to the lungs.

This means that the syrinx has two potential sound sources, one in each bronchus. The separate membranes on each bronchus produce separate sounds, which are then

mixed when fed into the higher vocal tract. This complex design means that birds can produce a far greater variety of sounds than humans can.

The best time to hear bird song is at dawn. The dawn chorus is one of the marvels of nature. Birds all over the world show the greatest amount of singing activity around dawn, be they from the European woodland or from the tropical rainforest. But why they prefer dawn to other times of day is still not clearly understood.

One reason may be that dawn is the best time for sound to travel, because there is little wind and less other noise and disturbance. Songs broadcast at dawn can be 20 times more effective than those broadcast at midday. And this is a time when birds can't do much else. Light intensity is low, making it difficult for them to hunt and forage. Low temperatures keep their insect prey on the ground.

By singing at dawn, when their energy reserves are low after the night, male birds may be telling females that they are nevertheless still fit for breeding. A male singing lustily is demonstrating that he has spare energy in abundance. Dawn may be a good time to sing, but there is likely to be a lot of vocal competition. So there are advantages to singing at a different time of the day, particularly when two different species have similar songs.

While singing behaviour varies among species, most takes place during the breeding season. Lags occur during the short mating period and when the young are being cared for. Singing pretty much stops when the nestling period is over. The songs of birds are learned, not inherited, much as with humans. Within a couple of months, fledglings will have developed a 'subsong' that matures into an adult primary song in perhaps a year.

The purpose of bird song is varied. They may sing to attract a mate or to establish and defend a nestling territory. Usually a male that is defending a territory or attracting a mate will sing from one of the highest or most conspicuous spots available Their singing is also a way to establish

identity of parents or chicks as also to indicate food and hunger. While flying they want to avoid collisions. They resort to singing at that time. It could also be a call for help and thus find each other when lost. Thus they sing on all sorts of occasions. Some birds are seen to sing more at springtime. Yet others are more lyrical as autumn approaches.

So when the birds sing would depend on the purpose of their singing. Even so, the early morning appears to be a favourite time of day when they sing. Their morning chorus is a performance that can be really enjoyed in any part of the globe.

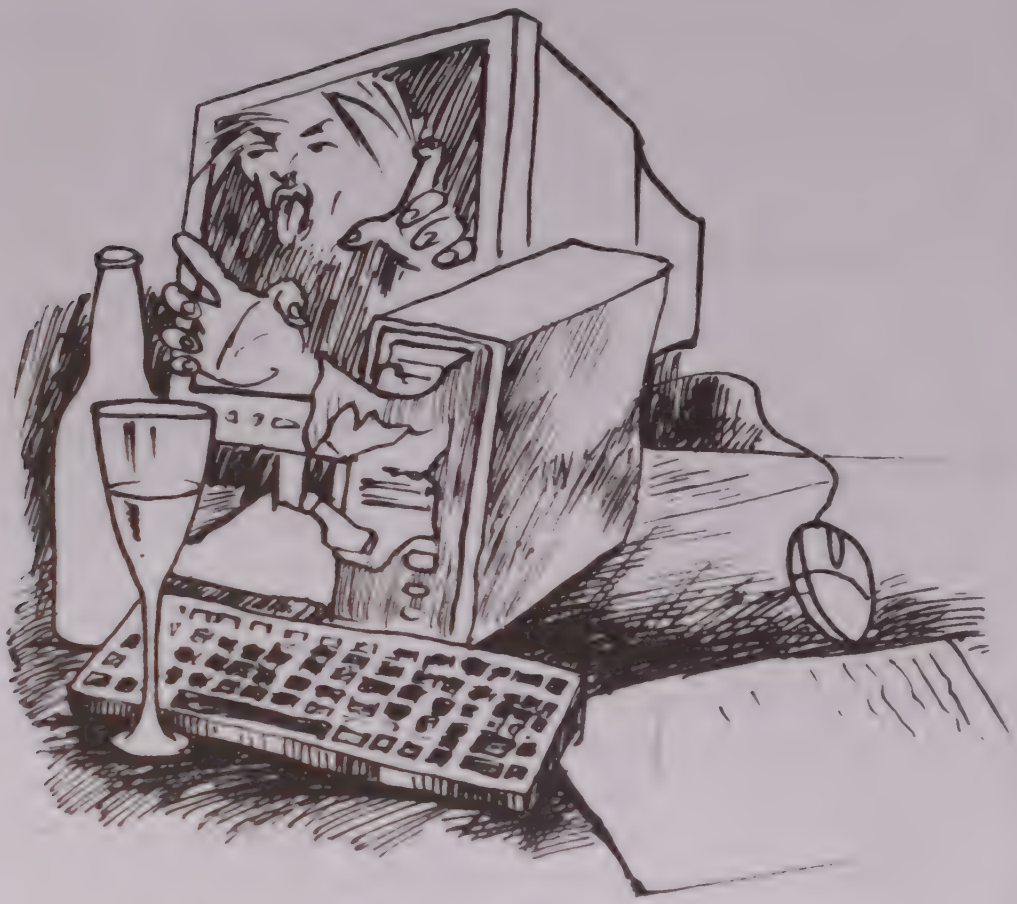
12

WHEN DO COMPUTERS CRASH?

Computer crash is a popular expression used to describe a serious computer failure. A computer crash means that the computer itself stops working or that a program aborts unexpectedly. A crash signifies either a hardware malfunction or a very serious software bug.

A computer is made up of a number of components. At its heart is a chip or an electronic circuit consisting of a large number of transistors and other electronic component. Power is needed to keep it working. It needs to interact with the user as also with components within the system. It also needs some display unit. All these together make up the personal computer sitting on your desk or your lap. All these equipment that are already wired together are collectively referred to as hardware.

But that is not enough. To make the computer do its work at the user's bidding, certain programs are needed. One of these is the operating system. This ensures that the computer operates properly and is able to respond to the user's demands. It acts as a matchmaker. On one hand, it understands the instructions given by the user in our common day-to-day language. On the other, it translates them into the mathematical language that the machine understands. Further, it transmits the information thus generated to the central processing unit (CPU) and its components. It also receives back from the CPU results of its labour. This is now carried back to the user by displaying it on the monitor screen again in a format that the user can relate to. The other kinds of programs allow the user tc



conduct specific functions, say, writing an article or drawing a picture or preparing an audio-visual. Collectively all the programs are known as software.

Computers crash because of errors in the operating system (OS) software or errors in the computer hardware. Software errors are probably more common, but hardware errors can be devastating and harder to diagnose.

A variety of hardware components must function correctly in order, for a computer to work. These components, like many things, age over time and can develop faults. Unfortunately, these faults are often transient, and can be hard to diagnose because they do not appear consistently. The system power supply can fail in this manner. Normally, a computer's power supply converts alternating current to clean direct current. If it starts to fail,

the computer can crash accidentally when the power supply generates a noisy signal.

The random access memory (RAM) can also fail in an intermittent way, particularly if it gets hot. Because the values RAM stores get corrupted unpredictably, it causes random system crashes. The CPU can also be the source of crashes due to excessive heat. The, often loud, fans on most common computers are there to prevent this type of crash, though they may eventually fail. The fans that bring cooling air into the case also carry dirt and dust inside. This dirt can accumulate and cause intermittent short circuits as the dirt blows around. Fortunately, compressed air or a vacuum cleaner easily gets rid of the dirt. Still other hardware problems that can cause crashes are trickier to identify and require software tests or sequential replacement of components.

More permanent faults happen with errors on a computer's disk. Each disk stores information in units named sectors. Most new disks come with bad sectors that occur in the manufacturing process and are marked at the factory. Makers expect this and include ample additional sectors to replace the defective ones. Sectors can go bad later, however, and lose the information stored on them. If these sectors happen to hold system information, they can cause a crash. Worse, a disk can fail completely when the computer gets jarred and the head that reads information makes contact with the disk surface. This may cause all data on the disk to be lost.

That said, it must also be stressed that the hardware in present-day computers is quite sturdy. It can start malfunctioning only when it gets very old or is subjected to some serious trauma like excessive heat or strong magnetic field or severe fluctuations in the electric supply. More often than not the cause for a computer crash would have to be found in the malfunctioning of the software. Of this, again, the operating system (OS) software is the primary culprit.

Perhaps the most common is a glitch that arises when the OS tries to access an incorrect memory address, perhaps as a result of a programming error. In Windows, this can lead to an error known as a General Protection Fault (GPF). Other errors drive the OS into an infinite loop. A loop is a series of instructions that gets repeated until a specified condition is met. When that condition can't be met, the loop cycles endlessly and never quits or moves to the next part of the program. In these cases, the computer might seem to 'lock up'. The system doesn't crash, but is no longer responsive to input and needs to be reset.

Thrashing is another problem condition. Any computer has a finite amount of memory and processing capabilities. When a process or program makes a request of the operating system that can't be met, the operating system borrows the necessary resources from another process. But then the borrowed-from process asks for resources, and the operating system has to find them somewhere else. Eventually, the entire system is looking for help, and the computer user is looking at a stagnant or blue screen.

Finally, there's the classic fatal error. There are certain commands that an ordinary user isn't allowed to issue. These typically have to do with the operation of the hardware, memory and processing of the machine. Sometimes, however, a program steps into that forbidden area and, to protect itself, the machine shuts down. That way, when you reboot, everything still works the way it should. Except for all the data you lost due to the shutdown.

Given so many reasons for the computer to lose its head and go into a sulk how can one say specifically when computers crash. All that one can assert with certainly is that it does so rarely.

13

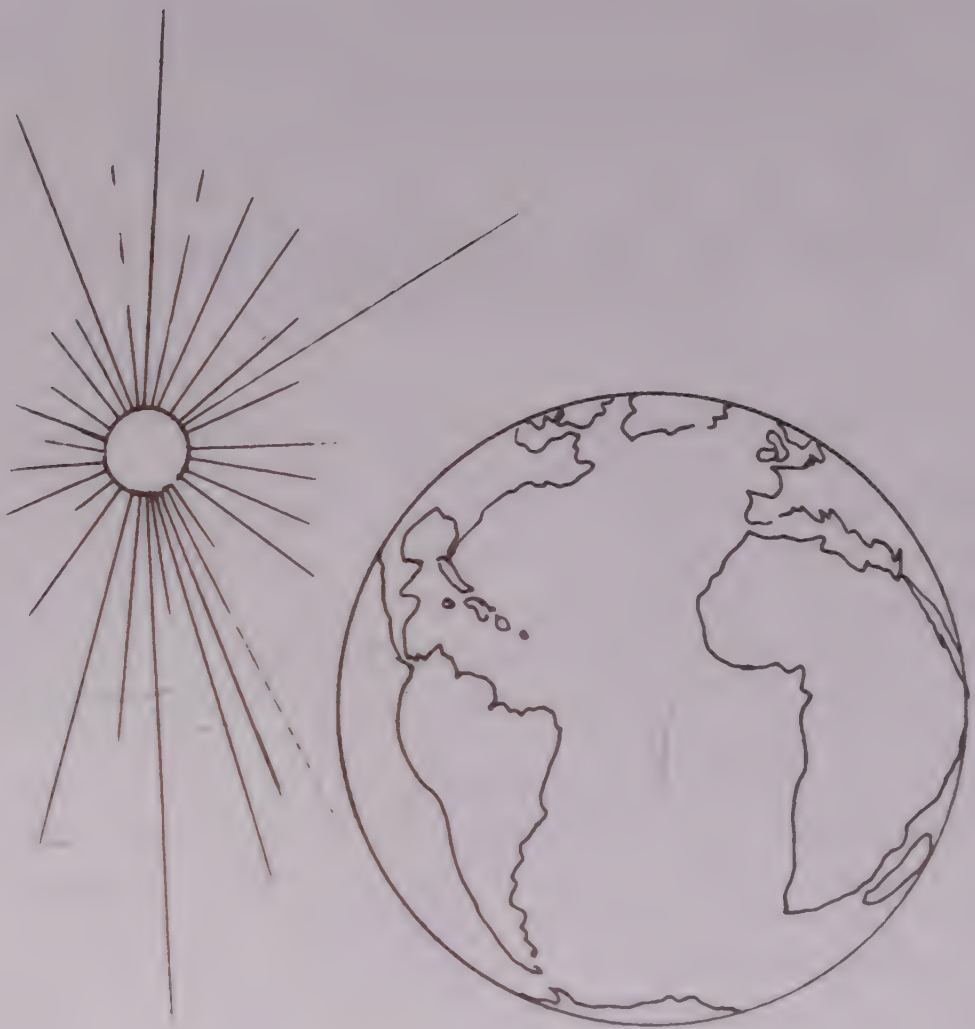
WHEN DO DAY AND NIGHT BECOME EQUAL IN LENGTH?

The question would probably be never asked in Singapore. Being very close to the equator the day and night are of equal length there almost throughout the year. Likewise at the two poles, north and south, the question would be meaningless. The two never become equal there. Either it is day for all the twenty four hours or it is night for the entire period. The Sun either never sets or never rises during the respective periods.

But at any other place in the world the question does acquire some importance. But that should give rise to another and related question. Why aren't the two equal all the time? Why should the equator have that distinction?

Strictly speaking day and night are arbitrary divisions of a 'day'. A 'day' is the time our earth takes to complete one lap around itself. Because it is constantly spinning around itself different parts of the globe are exposed to the Sun at different times. That is the reason that any particular location on the globe gets sunlight for a limited period of time. Ideally this should be for precisely 50 per cent of the time it takes to complete one round. This period when the spot is lighted by the Sun is called the day and the other part when there is no natural light, the night.

There are two different reasons why these two periods are not of equal length throughout the year. The first is that the axis around which the earth spins is tilted. It is not perpendicular to the plane in which the earth goes around the Sun. It makes an angle of about 23 degrees with this



21st March
23rd September
SUN

plane. Secondly the path of the earth's rotation around the sun is not circular but elliptical. Since the Sun is at the centre of this ellipse it means that the distance of the Sun from the earth varies as it goes around. It also implies that the Sun's rays do not hit the earth straight from above but at an angle at most of the places.

The first reason yields changes in the distribution of time over days and nights, and the effects are in the opposite direction in both hemispheres. So when the north has long days, the south has long nights, and vice versa. The second reason yields changes in the temperature but no changes in days and nights, and works in the same direction in both hemispheres. It is hotter everywhere in a hemisphere while it is colder everywhere in the other hemisphere.

Although, during full daylight, stars other than the Sun are overwhelmed by sunlight, making it hard to see where the Sun is compared to other celestial bodies, the Sun does have a position, as seen from Earth, relative to the other stars. As Earth moves around the Sun, the apparent position of the Sun relative to the other stars moves in a full circle over the period of a year. This circle is called the ecliptic, and is also the plane of Earth's orbit projected against the whole sky. The other bright planets like Venus, Mars and Saturn, also appear to move along the ecliptic, because their orbits are in a similar plane to Earth's.

Another virtual circle in the sky is the celestial equator, or the projection of the plane of Earth's equator against the whole sky. Because Earth's axis of rotation is tilted relative to the plane of Earth's orbit around the Sun, the celestial equator is inclined to the ecliptic by about 23.5 degrees.

Twice a year, the Sun, making its progress around the ecliptic, crosses the plane of Earth's equator. The two intersections between ecliptic and celestial equator are the equinoctial points. At these points equinoxes occur. *Equinox* is a latin word meaning 'equal night'. On the equinoxes, everywhere over the globe, the Sun rises true east, that is parallel to lines of latitude and sets at true west. As a result,

the length of the day equals the length of the night.

So the answer to the question would be that the day and night are of equal length on days of equinox. There are two such days in an year, 21st of March and 23rd of September. So the length of day should be the same as that of night on these dates.

However, it has been seen that it is not so. In fact, day and night are of equal length for a few days around the time of the equinoxes. Does it mean that all these astronomcial explanations and calculations are wrong? Not really. The discrepancey has a perfectly logical explanation.

On the day of an equinox, the geometric centre of the Sun's disk crosses the equator, and this point is above the horizon for 12 hours everywhere on the Earth. However, the Sun is not simply a geometric point. Sunrise is defined as the instant when the leading edge of the Sun's disk becomes visible on the horizon, whereas sunset is the instant when the trailing edge of the disk disappears below the horizon. These are the moments of first and last direct sunlight. At these times the centre of the disk is below the horizon. Furthermore, atmospheric refraction causes the Sun's disk to appear higher in the sky than it would if the Earth had no atmosphere. Thus, in the morning, the upper edge of the disk is visible for several minutes before the geometric edge of the disk reaches the horizon. Similarly, in the evening, the upper edge of the disk disappears several minutes after the geometric disk has passed below the horizon. The times of sunrise and sunset in almanacs are calculated for the normal atmospheric refraction of 34 minutes of arc and a semi-diameter of 16 minutes of arc for the disk. Therefore, at the tabulated time the geometric centre of the Sun is actually 50 minutes of arc below a regular and unobstructed horizon for an observer on the surface of the Earth in a level region.

For observers within a couple of degrees of the equator, the period from sunrise to sunset is always several minutes longer than the night. At higher latitudes in the northern

hemisphere, the date of equal day and night occurs before the March equinox. Daytime continues to be longer than nighttime until after the September equinox. In the southern hemisphere, the dates of equal day and night occur before the September equinox and after the March equinox. In the northern hemisphere, at latitude 5 degrees, the dates of equal day and night occur about February 25 and October 15. At latitude 40 degrees they occur about March 17 and September 26. On the dates of the equinoxes, the day is about 7 minutes longer than the night at latitudes up to about 25 degrees, increasing to 10 minutes or more at latitude 50 degrees.

So when are day and night of equal length? The dates on which day and night are each 12 hours occur a few days before and after the equinoxes. The specific dates of this occurrence are different for different latitudes.

14

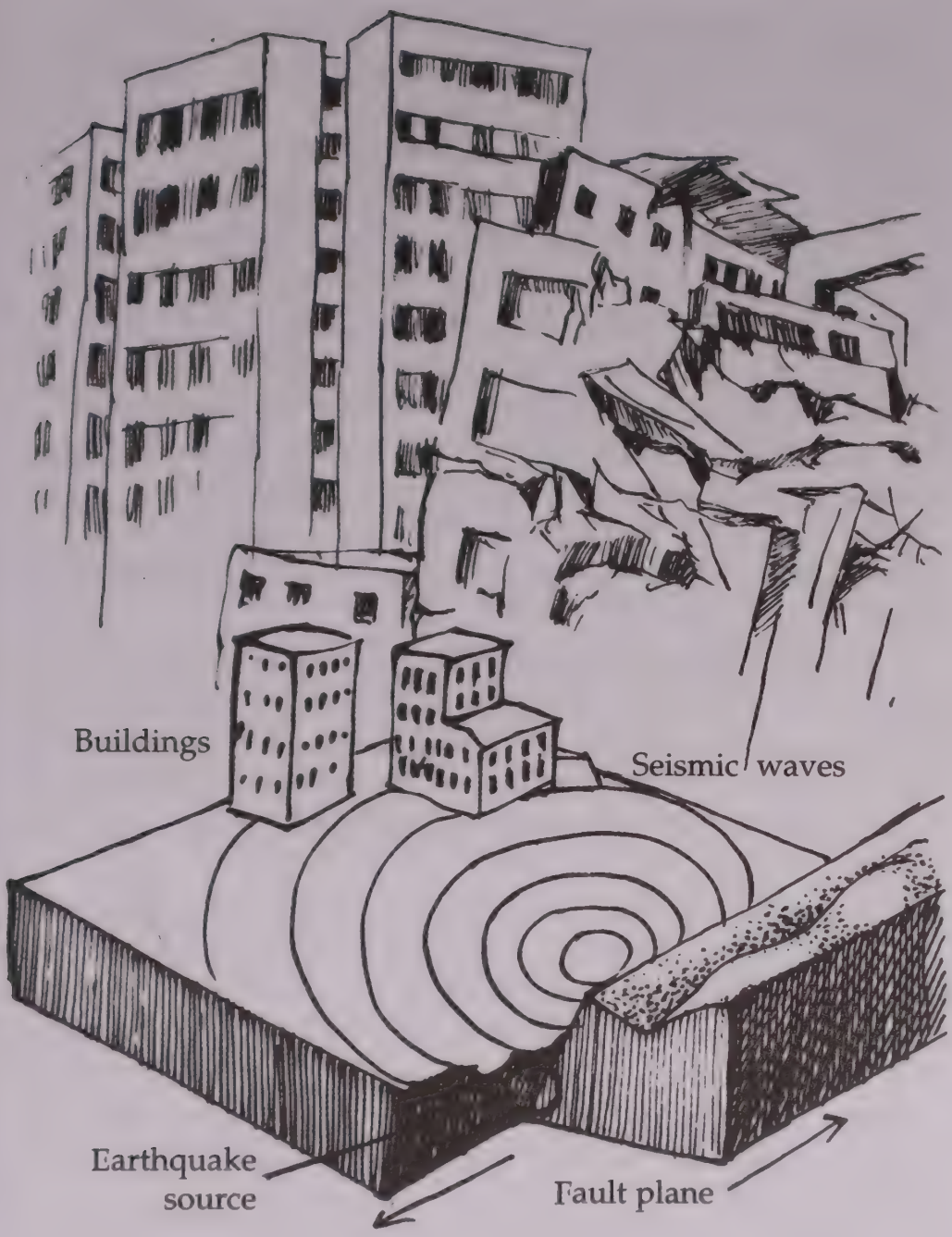
WHEN DO EARTHQUAKES OCCUR?

An earthquake is quite literally an earthshaking, groundbreaking event. We lovingly call the ground beneath us *terra firma*. That epithet is given to the earth because it also gives us a sense of security. We always need some support. Howsoever we would like to float in air like birds we are uncomfortable in such a situation. This is evident from the experience of astronauts who have, per force, to remain in such a state for a time. They accept it as a necessary evil but do not really enjoy it. That is why when the ground under our feet suddenly gives way, the illusion of safety that we have so assiduously built up, gets shattered.

Earthquakes occur without warning. The loss of life and property is very high. More than that it induces a sense of insecurity. If there is any premonition of such a cataclysmic event one may be able to take some proactive steps to protect those persons and items one values most. No such opportunity is given by an earthquake. Naturally, one keeps asking, perhaps forlornly, when does an earthquake occur?

An earthquake is the vibration, sometimes violent, of the Earth's surface that follows a release of energy in the Earth's crust. This energy can be generated by a sudden dislocation of segments of the crust, by a volcanic eruption, or even by manmade explosions. Most destructive quakes, however, are caused by dislocations of the crust.

The interior of the earth is made up of several layers. The outermost layer is called its crust. The crust is not one single continuous cover. It is made up of several pieces,



called plates. The plates under the oceans are called oceanic plates and the rest are continental plates. The plates are moved around by the motion of a deeper part of the earth, the mantle, that lies underneath the crust.

The plates cover the entire surface of the globe. It is,

thus, in continuous slow motion. This is plate tectonics, the motion of immense rigid plates at the surface of the Earth in response to flow of rock within the Earth. The plates usually move at about the same speed with which our fingernails grow. Since they are all moving they rub against each other in some places, sink beneath each other in others or spread apart from each other. At such places the motion isn't smooth. The plates are stuck together at the edges but the rest of each plate is continuing to move. So the rocks along the edges are distorted. Scientists call this strain. As the motion continues, the strain builds up to the point where the rock cannot withstand any more bending. With a lurch, the rock breaks and the two sides move. An earthquake is the shaking that radiates out from the breaking rock.

People have known about earthquakes for thousands of years, of course. But they didn't know what caused them. In particular, people believed that the breaks in the Earth's surface or faults, which appear after earthquakes, were caused 'by' the earthquakes rather than being the cause 'of' them.

It was Bunjiro Koto, a geologist in Japan studying a 100 km long fault whose two sides shifted about 5 metres in the great Japanese earthquake of 1871, who first suggested that earthquakes were caused by faults. Henry Reid, studying the great San Francisco earthquake of 1906, took the idea further. He said that an earthquake is a result of the huge amount of energy released when accumulated strain causes a fault to rupture. He explained that the rock, twisted further and further out of shape by continuing forces over the centuries, eventually yields in a wrenching snap as the two sides of the fault slip to a new position to relieve the strain.

There are three types of faults. Normal faults are the cracks where one block of rock is sliding downward and away from another block of rock. These faults usually occur in areas where a plate is very slowly splitting apart or where two plates are pulling away from each other.

Strike-slip faults are the cracks between two plates that are sliding past each other. The San Andreas fault is a strike-slip fault. It's the most famous California fault and has caused a lot of powerful earthquakes.

Reverse faults are cracks formed where one plate is pushing into another plate. They also occur where a plate is folding up because it's being compressed by another plate pushing against it. At these faults, one block of rock is sliding underneath another block or one block is being pushed up over the other. These type of faults are common in the Hindukush ranges of Himalayas that have experienced a large number of earthquakes.

Earthquakes are usually caused when the rock underground suddenly breaks along a fault. This sudden release of energy causes the seismic waves that make the ground shake. When two blocks of rock or two plates are rubbing against each other, they stick a little. They don't just slide smoothly; the rocks catch on each other. The rocks are still pushing against each other, but not moving. After a while, the rocks break because of all the pressure that's built up. When the rocks break, the earthquake occurs. During the earthquake and afterward, the plates or blocks of rock start moving, and they continue to move until they get stuck again. The spot underground where the rock breaks is called the 'focus' of the earthquake. The place right above the focus, on top of the ground, is called the 'epicentre' of the earthquake.

Earthquakes beneath the ocean floor sometimes generate immense sea waves or tsunamis. These waves travel across the ocean at speeds as great as 960 kilometers per hour and may be 15 m high or higher by the time they reach the shore. On 26 December 2004 an earthquake measuring 8.5 on the Richter scale occurred in the ocean near Bandar Aceh in Indonesia. That brought about a tsunami which resulted in the loss of thousands of lives and devastated large territories as far away as eastern shores of Africa.

It is fortunate that such destructive earthquakes are not

an everyday phenomena. That should not imply, however, that earthquakes are very rare. The very fact that the plates which make up earth's crust are constantly in motion should suggest that building up of strain must also be a continuous event. Consequently, the need for its release must also be constantly felt. This is true. There are over a million quakes annually, including those too small to be felt. Even so, as many as 95 per cent of them are very minor and do not cause any discernible damage. Some even do not get noticed except by highly sensitive instruments. Still, there can be more than 100 that can be categorised as large or destructive.

It is thus difficult to tell in an unequivocal manner when an earthquake occurs. All that one can state with some degree of confidence is that it occurs whenever the strain energy accumulated along the fault lines is in need of immediate release.

15

WHEN DO LEAVES CHANGE COLOUR?

Well, not all leaves do. There are trees that never shed their leaves or let the leaves change colour. These trees are known as evergreens. Most of the conifers, pines, spruces, firs, hemlocks, cedars, etc. belong to this category. They have needle- or scale-like leaves that remain green or greenish all the year round. Individual leaves may stay on for two to four or more years. It is mostly trees with broad leaves that go through the annual cycle of leaves changing colour which then fall off leaving the tree very bare and dismal looking. New leaf formation takes place subsequently and the tree regains all its majesty with a lush green foliage. These trees are known as deciduous trees.

The leaves of these trees owe their green colour to the pigment chlorophyll. Leaves are nature's food factories. Plants take water from the ground through their roots. They take a gas called carbon dioxide from the air. Plants use sunlight to turn water and carbon dioxide into glucose. Glucose is a kind of sugar. Plants use glucose as food for energy and as a building block for growing. The way plants turn water and carbon dioxide into sugar is called photosynthesis. The term means "putting together with light." Chlorophyll helps make photosynthesis happen. Chlorophyll is what gives plants their green colour.

But chlorophyll is not the only pigment present in leaves. There are others like Carotenoids, which produce yellow, orange, and brown colors in such things as corn, carrots, and daffodils, as well as bananas. Then there are Anthocyanins, which give colour to such familiar things as

cranberries, red apples, concord grapes, blueberries, cherries, strawberries, and plums. They are water soluble and appear in the watery liquid of leaf cells.

All through summer, with the long hours of sunlight and a good supply of liquid water, plants are busy making and storing food, and growing. During summer days, leaves make more glucose than what the plant needs for energy and growth. The excess is turned into starch and stored until needed. As the daylight gets shorter in the autumn, plants begin to shut down their food production.

During the growing season, chlorophyll is continually being produced and broken down and leaves appear green. The other pigments get masked though they are very much there. But as autumn approaches, certain influences both inside and outside the plant cause the chlorophylls to be replaced at a slower rate than they are being used up. During this period, with the total supply of chlorophylls gradually dwindling, the "masking" effect slowly fades away. Then other pigments that are present, along with the chlorophylls, begin to show through. These are the carotenoids; they give us colourations of yellow, brown, orange, and the many hues in between.

At the same time other chemical changes may occur, which form additional colours through the development of red anthocyanin pigments. Some mixtures give rise to the reddish and purplish fall colours of trees such as dogwoods and sumacs, while others give the sugar maple its brilliant orange.

The autumn foliage of some trees show only yellow colours. Others, like many oaks, display mostly browns. All these colours are due to the mixing of varying amounts of the chlorophyll residue and other pigments in the leaf during the fall season.

As the fall colours appear, other changes too take place. At the point where the stem of the leaf is attached to the tree, a special layer of cells develops and gradually severs the tissues that support the leaf. At the same time, the tree seals the cut, so that when the leaf is finally blown off by the wind or falls from its own weight, it leaves behind a leaf scar.

Certain colours are characteristic of particular species. Oaks turn red, brown, or russet; hickories—golden bronze; aspen and yellow-poplar—golden yellow; dogwood—purplish red; beech—light tan; and sourwood and black tupelo—crimson. Maples differ species by species: red maple turns brilliant scarlet; sugar maple—orange-red; and black maple—glowing yellow. Striped maple becomes almost

colourless. Leaves of some species such as the elms simply shrivel up and fall, exhibiting little colour other than drab brown.

The timing of the colour change also varies by species. Sourwood can become vividly colourful in late summer when all other species are still vigorously green. Oaks put on their colours long after other species have already shed their leaves. These differences in timing among species seem to be genetically inherited; a particular species at the same latitude will show the same colouration in the cool temperatures of high mountain elevations at about the same time as it does in warmer lowlands.

A succession of warm, sunny days and cool, crisp but not freezing nights seems to bring about the most spectacular colour displays. During these days, lots of sugars are produced in the leaf but the cool nights and the gradual closing of veins going into the leaf prevent these sugars from moving out. These conditions, lots of sugar and lots of light, spur production of the brilliant anthocyanin pigments, which tint reds, purples, and crimson. Because carotenoids are always present in leaves, the yellow and gold colours remain fairly constant from year to year.

The brightest colours are seen when late summer is dry, and autumn has bright sunny days and cool nights. Then trees make a lot of anthocyanin pigments.

So, when do leaves change colour? They do so during autumn as the length of day decreases and that of the night slowly increases along with a fall in the ambient temperature. This is the reason that this brilliant display of colour is more spectacular at high latitudes. The difference in the length of day and night is much more there as also difference in the summer and winter temperatures.

16

WHEN DO WE DREAM?

Of course, we dream during our sleep, when else? What a silly question to ask! That may be your immediate reaction. You may well be justified in coming up with such a response. But, with a little thought you would most probably come to the conclusion that it is not such an inane question after all. Contrary to common belief, our sleep is not a single homogeneous period. It consists of five distinct phases. That became known after the path-breaking discovery by Eugene Aserinski in 1953. He noticed that the eyes of sleeping babies moved beneath their eyelids at certain regular intervals. This led to the discovery of REM (Rapid Eye Movement) sleep periods, which occur at roughly 60-90 minute intervals throughout the night. It also inspired interest in sleep research by giving scientists a marker for detecting changes in the brain during sleep.

Everyone sleeps. This fundamental activity consumes one-third of our lifetimes and can overpower all other needs. Before the 1950s, most scientists thought of sleep as an unchanging, dormant period of little interest. The earliest hints that sleep was a changing state came with studies showing that blood pressure, heart rate, and other body functions in humans rise and fall in a pattern during sleep. Because researchers had observed some eye movement during sleep, they recorded these movements by placing electrodes behind the eyes. They also recorded muscle activity and brain waves. Brain waves are fluctuations in the electrical activity of the brain that can be measured with the help of electrodes. They found regular periods of

very rapid eye movement and rapidly changing brain waves that alternated with periods of deep, quiet, sleep marked by large, slow brain waves. Later, scientists found that the body is paralysed during REM sleep.

During sleep, we usually pass through five phases of sleep. These stages progress in a cycle from stage 1 to rapid-eye-movement (REM) sleep, then the cycle starts all over again with stage 1. We spend almost 50 per cent of our total sleep time in stage 2 sleep, about 20 per cent in REM sleep, and the remaining 30 per cent in the other stages. Infants, by contrast, spend about half of their sleep time in REM sleep.

During stage 1, which is light sleep, we drift in and out of sleep and can be awakened easily. Our eyes move very slowly and muscle activity slows. People awakened from stage 1 sleep, often remember fragmented visual images. Many also experience sudden muscle contractions called hypnic myoclonia, often preceded by a sensation of starting to fall. These sudden movements are similar to the "jump" we make when startled.

When we enter stage 2 sleep, our eye movements stop and our brain waves become slower, with occasional bursts of rapid waves called sleep spindles.

In stage 3, extremely slow brain waves called delta waves begin to appear, interspersed with smaller, faster waves.

By stage 4, the brain produces delta waves almost exclusively. It is very difficult to wake someone during stages 3 and 4, which together are called deep sleep. There is no eye movement or muscle activity. People awakened during deep sleep do not adjust immediately and often feel groggy and disoriented for several minutes after they wake up. Some children experience bedwetting, night terrors, or sleepwalking during deep sleep.

When we switch into REM sleep, our breathing becomes more rapid, irregular, and shallow, our eyes jerk rapidly in various directions, and our limb muscles become

temporarily paralysed. Our heart rate increases, our blood pressure rises, and males develop penile erections. When researchers woke people up during REM sleep and asked them about their dreams, they found that almost all who awakened during REM sleep could remember their dreams. They realised that people who claim they do not dream really do not remember their dreams the next morning. Also, scientists found that, rather than being fleeting events, dreams vary in length according to the length of REM period.

The first REM sleep period usually occurs about 70 to 90 minutes after we fall asleep. A complete sleep cycle takes 90 to 110 minutes on an average. Each night, the first sleep cycles contain relatively short REM periods and long periods of deep sleep. As the night progresses, REM sleep periods increase in length while deep sleep decreases. By morning, people spend nearly all their sleep time in stages 1, 2, and REM.

Scientists found that brain activity during REM sleep begins in the pons, a structure in the brain-stem, and neighbouring mid-brain regions. The pons sends signals to the thalamus and to the cerebral cortex, which is responsible for most thought processes. It also sends signals to turn off motor neurons in the spinal cord, causing a temporary paralysis that prevents movement.

Many theories about the function of sleep concentrate mainly on REM sleep, and many people believe that we only go to sleep for the purpose of dreaming or having REM sleep. Dreams are usually pleasant and entertaining. We tend to dream in the same style as we think during wakefulness. Dreams total around 100 minutes a night, but we can seldom recollect more than a few minutes worth. Dreams cannot be remembered unless one wakes up out of one and immediately thinks about it, when it can then be stored into one's memory. The underlying REM sleep may well stimulate and tone up the sleeping brain, thus preparing it for wakefulness.

The total period of REM sleep and the period spent in dreaming decreases as we age. During childhood the REM sleep constitutes almost 40 per cent of the total sleep. But in old age this reduces to less than 10 per cent. REM sleep and dreams are thought to play a major role in building up of memory.

There is a general perception that dreams that occur in the early morning hours come true. Going over the different cycles of sleep it is easily seen that the intervals between successive REM periods is significantly reduced in these wee hours. Thus one spends relatively more time in REM sleep as dawn nears. Consequently, more dreams occur at that time. Also since one wakes up soon thereafter, one tends to remember these dreams more vividly than the others. That might be the basis that has given rise to this perception which is most probably wishful thinking.

So one need not dismiss the question when do we dream. One can confidently answer it. We dream during the REM phases of sleep.

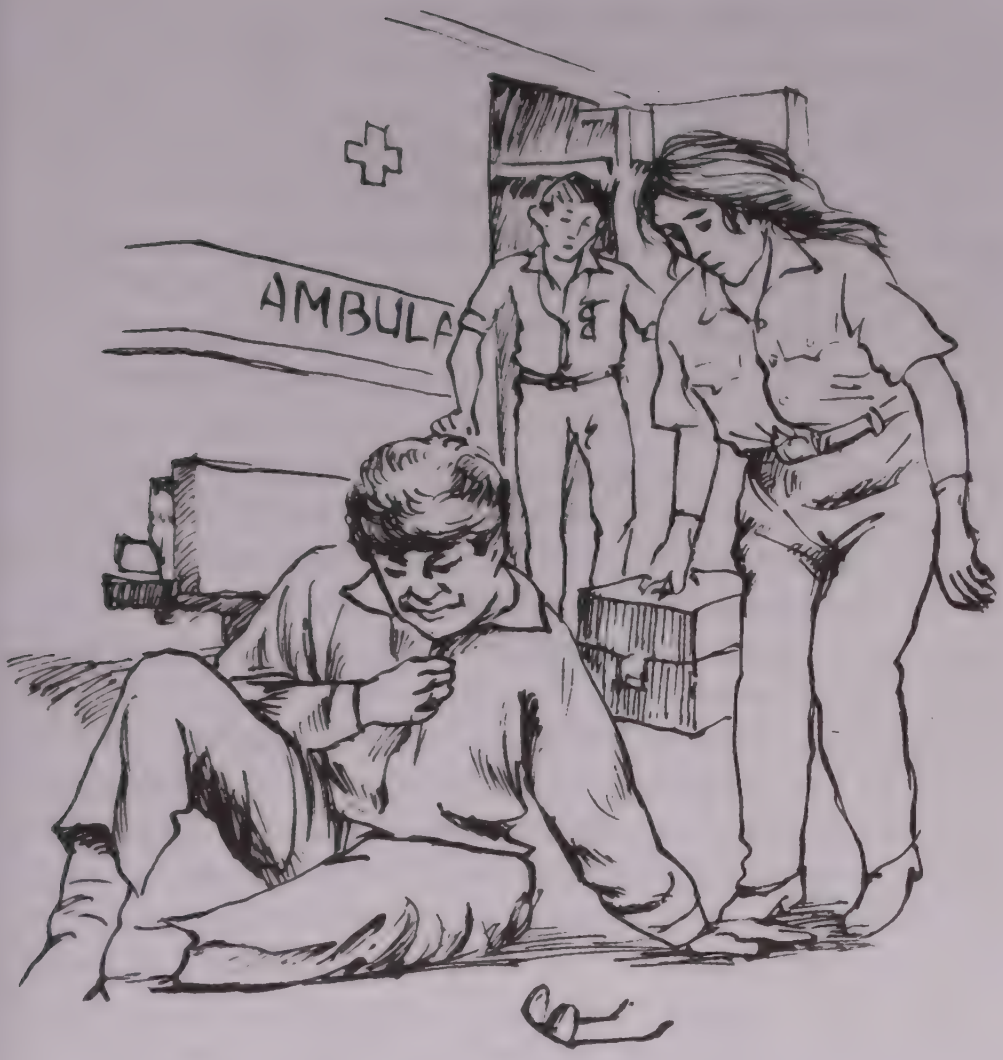
17

WHEN DO WE GET HEART ATTACK?

Heart attack is an expression that is used by common people to describe what the doctors call myocardial infarction. Infarction means death. Myocardial implies relating to heart muscle. In other words, the term myocardial infarction translates as death of the heart muscle. That may sound weird but it is very close to the truth.

The organ heart has been described by litterateurs in such romantic terms that we tend to forget its real nature. It is but a pump. It receives the impure blood lacking in oxygen and full of carbon dioxide from all over the body. It pumps this blood to the nearby lungs for the purpose of restoring its oxygen content to the normal level. In return it receives the oxygenated or pure blood from the lungs, which it pumps powerfully to all nooks and corners of the body. Since that is a vast territory this pumping action has to be carried out with considerable force.

The pump is made up of muscles. That is why like all other muscles in the body it requires adequate energy. Moreover, since this muscular pump is never at rest throughout the life of the individual it needs to have an uninterrupted supply of energy. That it gets from the blood supply through arteries that sit on its top. There may be a lot of blood inside the heart. But that is of no use as far as the energy supply is concerned. It has to obtain that energy like every other muscle from the artery connected to it. The situation is like an oil tanker. The tanker may carry thousands of litres of petrol or diesel but that cannot be of any help to it in its running. For that purpose the fuel has to



come from its own much smaller fuel tank.

These arteries sit atop the heart in such a way that it seems the organ is wearing a crown. That is why the arteries came to be known as the coronary arteries. If there is any blockage in these arteries, it results in stoppage of blood and hence crucial oxygen to a part of the heart muscle. When the heart muscle is deprived of this crucial energy-giving feed, it begins to die. If blood flow is not restored within 20 to 40 minutes, irreversible death of the heart muscle will begin to occur. Muscle continues to die for 6-8 hours at which time the heart attack usually is "complete." The dead heart muscle is replaced by a scar tissue.

Naturally one would like to know when does this blockage or complete stoppage of blood supply to the heart muscle occur. This results from a condition known as atherosclerosis. Atherosclerosis is a gradual process in which plaques or collections of cholesterol are deposited on the walls of arteries. Cholesterol plaques cause hardening of the arterial walls and narrowing of the inner channel of the artery. Arteries that are narrowed by atherosclerosis cannot deliver enough blood to maintain normal function of the parts of the body that they supply. For example, atherosclerosis of the arteries in the legs causes reduced blood flow to the legs. Reduced blood flow to the legs can lead to pain in the legs while walking or exercising, leg ulcers, or a delay in the healing of wounds to the legs. Likewise atherosclerosis of the coronary arteries would cause a heart attack.

Coronary atherosclerosis or coronary artery disease refers to the atherosclerosis that causes hardening and narrowing of the coronary arteries. Diseases caused by the reduced blood supply to the heart muscle from coronary atherosclerosis are called coronary heart diseases which include heart attacks.

In many people, atherosclerosis can remain silent causing no symptoms or health problems for years or decades. Atherosclerosis can begin as early as the teenage years, but symptoms or health problems usually do not arise until late in adulthood when the arterial narrowing becomes severe. So a heart attack can affect a person anytime during his life, though the probability increases with age.

Occasionally, the surface of a cholesterol plaque in a coronary artery may rupture, and a blood clot forms on the surface of the plaque. The clot blocks the flow of blood through the artery and results in a heart attack. The cause of rupture that leads to the formation of a clot is largely unknown, but contributing factors may include cigarette smoking or other nicotine exposure, elevated levels of LDL cholesterol, elevated levels of blood adrenaline, high blood

pressure, and other mechanical and biochemical forces.

Do heart attacks occur at any time during the day? To determine if the onset of a heart attack occurs randomly throughout the day scientists analysed the time of its beginning in 3000 patients admitted in a hospital with such a complaint. They found that there is a marked daily rhythm that this condition follows. While the attacks took place at any time there was a distinct peak from 6 in the morning to noon. In almost 25 per cent of these patients the first tell tale signs that heralded the attack were seen during this morning period. Naturally scientists tried to find out the underlying causes. They found that during morning hours the adrenal glands release more adrenaline. Consequently, its level in the blood rises. Increased adrenaline may contribute to rupture of the cholesterol plaques leading to formation of a blood clot. Should this happen, it blocks the blood vessel, cutting off the supply of blood and oxygen to the muscle.

So when does a heart attack occur? It may occur at any time during a day and at any time during one's life. However, the probability of its happening is higher at more ripe age and during the morning hours.

18

WHEN DO WE SEE AN OBJECT?

Of course, we see it the moment we set our eyes on that object. Don't we? If our sighting of an object was not instantaneous, why would the various television channels vie with each other to offer us live telecasts of happenings around the world? Did we not all see the World Trade Centre Tower, the moment that plane rammed through its upper floors? Then again did we not see those towers even as they were crumbling down?

Well, you may be right in suggesting that our sighting of things is indeed instantaneous, supported, as the suggestion is, by live telecasts of all these incidents, some macabre others pleasant. But let us pause for a moment and think about the question in an objective manner. How do we get to see an object?

Light rays emanating from that object reach our eyes and fall upon the retina. The rods and cones, cells that constitute the retina, absorb that light. The electrochemical pulse that is generated as a result is then transported by the optic nerve fibres to the concerned centre in our brain. There the pulses are anlaysed, the information received is compared with that stored in various locations of memory and the message is deciphered. Only then do we get to see that object and identify it for what it is.

The process thus is not as simple as we think it is. All these physical, chemical and biochemical reactions do take some time. Even the rays of light coming from the object do take their own time to reach us. The exact magnitude of that time would depend upon the intervening distance.

Now light does travel at the mind boggling speed of 300,000 km per second. Even so, it takes a finite time to cover the distance from the object to our eyes. That distance may be a few meters. In that case the light rays might need a billionth or at least a few hundred millionths of a second to reach the retina. Further processing of that signal would occupy a few more hundred millionths of seconds. So totally it would take time of the same order for us to be able to see that object. That time may be miniscule but is not zero in the strictest sense. So the question when do we see an object is not all that inconsequential after all, is it?

So far we have considered only objects that are on the surface of the earth. To an extent, our visibility is restricted as far as the sky is concerned, because of its curvature or other factors such as pollution. But when it comes to objects in outer space that visibility does get extended several fold. That is why we are easily able to see the moon, the sun, some other planets in our own solar system, even distant stars, comets and such celestial bodies. The distances of these objects are not insignificant in terms of the velocity of light.

The moon, for instance, is some 384,000 kilometers away. So it would take a full second before sunlight reflected from the moon's surface would reach us. The sun itself is so far away that its light takes around 8 minutes to reach us. In other words, when we see the sun it is not what it is or where it is at that particular instant. We see it as it was some eight minutes earlier. Can we then say without batting an eyelid that we are having a live view of the Sun?

There are other heavenly bodies which are even further away. To talk of their distances our usual measures of kilometers or miles are inadequate. One has to devise a new unit called the light year. It is the distance that light would cover in one full year, that is 60 x 60 x 24 x 365 seconds. And that too with its dizzying speed of 300,000 km per second. Even the thought of computing that distance takes our breath away. But the real point is that light rays

emanating from such a far away body would take that many years to get to us.

Some of these objects are so far away that it has taken the same amount of time that our universe has been in existence to reach us. In other words, we are not seeing that star at this very instant but as it was at the time the universe came into being. For all we know today that star may not be there at all. It might have lived its life and died giving birth to a spectacular supernova. If it indeed has we may never get to see that event in our lifetime. Some future descendents of ours, a few generations down the line, may be fortunate enough to witness that magnificent event. But what they would be able to see would have actually taken place in our lifetime. If the question 'when did they get to see that event' is put to them what honest reply can they give?

Meticulous tables prepared employing the most sophisticated software giving times of moonrise are now routinely included in various almanacs. These are expected to help those individuals who have vowed to partake their evening meals precisely at the moment the moon ascends the horizon. Since the moonlight takes only a little over a second to reach us, they may not experience much difficulty in keeping their vows. But do similar tables serve well for those who do not want to imbibe even a drop of water during the supposedly vile influence of a solar eclipse? Which are the times mentioned in these tables? The time when the earth actually comes out of the lunar shadow? Or is it the time when we get to see again the obscured sun? The two times would be some eight minutes apart. Some very hungry individual might actually be eating heartily during that interregnum. No calamity would befall him for the eclipse does not have any such ill influence. But were that individual to be informed of this incongruity of our sighting an event, would he be able to digest that meal he has tucked away with gusto?

So we get back to our original question. When do we

see an object? It would be difficult to answer that question in a very unequivocal manner. We would have to know the distance of that object before we can attempt to draft our response. All that we can say with a degree of certainty is that we get to see the object some time, howsoever miniscule, after we set our eyes on it.

19

WHEN DO WE YAWN?

That is simple, everyone would say. We yawn when we are tired or bored. It's widely assumed that yawning occurs because we are tired or bored or because we see someone else doing it, but there isn't any hard evidence to support these beliefs. The truth is that we don't completely understand why people, or animals for that matter, yawn.

Everyone yawns—babies, kids, teenagers, adults. Some birds, reptiles and most mammals also yawn. However, the reason why we yawn is a bit of a mystery. There is also very little research about yawning because for most people yawning is not a problem. Here are a few things that are known about yawns.

The average duration of a yawn is about 6 seconds. In humans, the earliest occurrence of a yawn happens at about 11 weeks after conception—that's *before* the baby is born! Yawns become contagious to people between the first and second years of life. A part of the brain that plays an important role in yawning is the hypothalamus. Research has shown that some neurotransmitters, for example, dopamine, excitatory amino acids, nitric oxide and neuropeptides increase yawning if injected into the hypothalamus of animals.

Yawning is a stereotypical reflex characterised by a single deep inhalation, with the mouth open and stretching of muscles of the jaw and trunk. It occurs in many animals, including humans, and involves interactions between the unconscious brain and the body, though the mechanism remains unclear. As for the etiology of yawning, for many

years it was thought that yawns served to bring in more air because low oxygen levels were sensed in the lungs. We now know, however, that the lungs do not necessarily sense oxygen levels. Moreover, fetuses yawn while they are still in mother's womb even though their lungs aren't yet ventilated!

In addition, different regions of the brain control yawning and breathing. Still, low oxygen levels in the paraventricular nucleus (PVN) of the hypothalamus of the brain can induce yawning. Another hypothesis is that we yawn because we are tired or bored. But this too is probably not the case because the PVN also plays a role in penile erection, which is not typically an event associated with boredom.

It does appear that the PVN of the hypothalamus is, among other things, the "yawning centre" of the brain. It contains a number of chemical messengers that can induce yawns, including dopamine, glycine, oxytocin and adrenocorticotropic hormone (ACTH). ACTH, for one, surges at night and prior to awakening, and induces yawning and stretching behaviour in humans. The process of yawning also appears to require production of nitric oxide by specific neurons in the PVN. Once stimulated, the cells of the PVN activate cells of the brain stem and/or hippocampus, causing yawning to occur. Yawning likewise appears to have a feedback component: If you stifle or prevent a yawn, the process is somewhat unsatisfying. The stretching of jaw and face muscles seems to be necessary for a yawn to be satisfying.

You know that when you are bored, you yawn. Scientists have confirmed this observation by comparing the number of yawns in 17-19 year old students who watched music videos to the number of yawns in students who watched an uninteresting colour test bar pattern. As you might have expected, people who watched the colour test bar pattern yawned more (5.78 yawns in 30 minutes) than those who watched the "MTV-like" video (3.41 yawns in 30 minutes). The average duration of yawns was also slightly longer in the test bar viewing group. One unexpected finding was that yawns in male students had a longer duration than those in female students.

One theory about yawning suggests that when one yawns, his or her alertness is heightened, as the sudden intake of oxygen increases the heart rate, rids the lungs and the bloodstream of the carbon dioxide build-up, and forces oxygen through blood vessels in the brain, while restoring normal breathing and ventilating the lungs.

Many people assume that we yawn because our bodies are trying to get rid of extra carbon dioxide (CO_2) and to take in more oxygen (O_2). This may make some sense. According to this theory, when people are bored or tired,

they breathe more slowly. As breathing slows down, less oxygen makes it to the lungs. As carbon dioxide builds up in the blood, a message to the brain results in signals back to the lungs saying, "Take a deep breath," and a yawn is produced.

The only problem with the excess CO_2 theory is that research shows that it may not be true. In 1987, Dr. Robert Provine and his co-workers set up an experiment to test the theory that high CO_2 / low O_2 blood content causes yawning. Air is normally made up of 20.95 per cent O_2; 79.02 per cent N_2 (nitrogen); 0.03 per cent CO_2; and a few other gases in low concentrations.

The researchers gave college students the following gases to breathe for 30 minutes: Gas no. 1— 100% O_2; Gas no. 2—3% CO_2 with 21% O_2; Gas no. 3—5% CO_2 with 21% O_2; and Gas no. 4—pure air.

Breathing 100% O_2 (Gas no. 1) or a mixture containing some CO_2 gas (Gas no. 2 and no. 3) did cause the students to breathe at a faster rate. However, neither CO_2 gas nor 100% O_2 caused the students to yawn more. These gases also did not change the duration of yawns when they occurred.

The researchers also looked for a relationship between breathing and yawning by having people exercise. Exercise, obviously, causes people to breathe faster. However, the number of yawns during exercise was not different from the number of yawns before or after exercise. Therefore, it appears that yawning is not due to CO_2 / O_2 levels in the blood and that yawning and breathing are controlled by different mechanisms.

So when do we yawn? A truthful and simple answer to that question is we do not know. We certainly seem to do so when we feel tired. But that may be incidental and not constitute a cause-effect relationship.

20

WHEN DO WHALES DIE?

Whales, the killer variety notwithstanding, are magnificent aquatic mammals. They are large and intelligent. Unlike fish who breathe using gills, whales breathe air through blowhole(s) into lungs. Whales have sleek, streamlined bodies that move easily through the water. They are the only mammals, other than manatees (seacows), that live their entire lives in the water, and the only mammals that have adapted to life in the open oceans.

Like all mammals, whales breathe air into lungs. They have hair although a lot less than land mammals. And they have almost none as adults. Whales are warm-blooded creatures. They maintain a high body temperature. Whales have mammary glands with which they nourish their young. They also have a four-chambered heart. They are thus a natural treasure.

However, they also are a part of the red list because they are in danger of becoming extinct. The reason for their becoming an endangered species is not far to be found. Excessive hunting of these mammals has resulted in rapid dwindling of their numbers. Conservationists the world over have demanded a moratorium on their hunting. That call has not been heeded by some countries. Norway, for example, has not only made it legal to hunt whales but has also earmarked certain periods in a year as official whale hunting season.

The Norwegian government has set a quota of 670 minke whales for the season, which runs from the first week of May until 31 August. The Scandinavian nation is the only

one in the world that authorises whaling for commercial purposes. Iceland and Japan are the only other nations to fish whales, though they claim to do so for scientific reasons.

The Scandinavian country argues that the hunt is needed to stop the whale population from growing so large that it devours huge stocks of fish. It says the minke whale population levels remain healthy and are not endangered by its annual hunt.

Even the technique employed in these hunts has become controversial. Norwegian whalers use harpoons to attack the animals. These are tipped with grenades. Once the harpoon hits the target the grenade gets lodged inside the body of the animal and explodes. They claim that the internal explosion kills the beast instantaneously. That contention is contested by environmentalists. They argue

that the lack of movement is used as a criterion of death. That is dubious. The animal is still alive at that stage and, in fact, suffers an agonising death. If their killing cannot be avoided, at least they should be given a humane death, they plead.

The controversy does not seem to be dying. It has brought to the surface the very crucial question, when does the whale die? A coalition of 140 animal welfare groups, Whalewatch, says many whales do not die quickly when hit, and tests to decide exactly when a whale is dead are inadequate. The well-known UK naturalist Sir David Attenborough says in a foreword that Whalewatch's report shows that "there is no humane way to kill a whale at sea". Whalewatch has been lobbying the International Whaling Commission (IWC) to halt all commercial and scientific whaling, to maintain the commercial whaling moratorium in force since 1986, and to concentrate on the issue of cruelty.

Sir David's foreword quotes Dr Harry Lillie, a ship's physician on an Antarctic whaling trip in the 1940s. Dr Lillie wrote: "If we can imagine a horse having two or three explosive spears stuck in its stomach and being made to pull a butcher's truck through the streets of London while it pours blood into the gutter, we shall have an idea of the method of killing".

But Dr Siri Knudsen from the Norwegian School of Veterinary Science, argues that the present tests may be overestimating the time taken for the animals to die. She tells the *Veterinary Journal* that the available data suggests that the grenade harpoons developed by Norwegian whalers, and the special training they have received to use them, make for a far more effective slaughter process than many people realise.

With the expert opinion so divergently divided, the question, when does the harpooned whale die, has assumed considerable importance. The criteria used by the IWC since 1980 to determine death in these marine mammals rely on observations—looking for the jaw and flipper to slacken,

and for all movement to cease. One small Norwegian study found this happened instantaneously in about 20 per cent of cases; in other cases, movement could be seen to continue for several seconds or minutes after harpooning.

Dr. Knudsen counters this by arguing that many of the animals that were seen to move after detonation were also very probably dead. She goes on to suggest that spinal cord reflexes might cause whales to move long after they have lost consciousness. And she uses as support for her view scientific observations that seals will withdraw their heads, open their jaws and arch their backs long after their brains have been totally destroyed.

But she rejects the idea of studies that would deploy technical equipment such as EEG to test for insensibility or death in an animal, calling it impractical and dangerous. "The animals are large and cannot be restrained or handled before they are dead. The minke whale may weigh up to 10 tonnes," she says. "Testing of reflexes or other physiological parameters on these large animals in such cold water, which has been proposed repeatedly, may put people's lives in danger." She calls for post-mortem studies, instead, to settle the issue. However, Dr Andy Butterworth, a veterinary scientist at the University of Bristol, UK, said that the post-mortem studies would only reduce figures for time to death.

Obviously there is no unanimity among the scientists on even deciding the criteria for determining the time of the animal's death after it has been hit by the harpoon. So with all these arguments and counter-arguments flying fast in the face of each other, the answer to the basic question, when does the whale die, remains as elusive and remote as ever.

21

WHEN DOES A BALL SWING?

It is not waltzing to the tunes of Beatles or Rolling Stones that one is talking about. On the contrary, one is concerned here about the red cherry doing all kinds of tricks at Lords. It is the cricket ball that veers away from the straight and narrow path and deviates on either side that one is worried about. Before we get into the commentary box and start analysing what the speed merchants are up to, let us be very clear what we mean by the term 'swing'.

The lateral deviation on either side of the direction in which a cricket ball is moving is called its swing. If, as a result of such movement—while the ball is still travelling through air—it veers towards the batsman, it is called an in-swinger. On the other hand, if the ball moves away from the batsman it is called an out-swinger. Several bowlers can bowl both types of balls, though usually one masters one type in a specific manner.

Only fast bowlers can bowl swinging balls. When the atmosphere is heavy, because of moisture in the air, the ball swings more than usual. These two observations should provide a clue to the mystery of the swinging ball. The key to make a cricket ball swing is to cause a pressure difference between the two sides of the ball. The air pressure depends on the flow of air over each side of the ball. Swing is generated when bowlers, by accident or design, disrupt the flow of air over one side of the ball.

Since the ball is smooth and spherical, one may wonder how can it have two sides. Also the spherical nature of the ball should make the air flow in the same way all round.

There are two other characteristics of the ball, however, that make a distinct difference. The ball is stitched and the seam is quite prominent. That causes an obstruction to the continuous flow of air around it. Secondly, as the ball gets hit hard by the batsman and has to travel on the ground through grass as well as bare patches of soil, some parts of the surface start getting rougher and rougher as the game progresses.

In simple terms, the ball will only change its flight path towards the batsman when air around the surface of the ball travels at different speeds. Remember the ball pushes air aside as it travels forward. Why? Because the air displaced by the ball must go somewhere else.

To understand this better you may conduct a simple experiment. Hold a small strip of of paper between your fingers close to your lips. Now blow over that strip. Contrary to your expectations you would find that the paper strip that was hanging limply till then suddenly stiffens and climbs to a horizontal position. This is because you have fast moving air on one side of the strip and slow moving air on the bottom side. So the paper is 'sucked' up into the faster air current. This is the same principle on which take off of airplanes is based.

The cricket ball does the same thing. A bowler creates this difference in the speed of air on the two sides of a ball using the seam or surface of the ball. The two sides of the ball are known as the shiny side and the rough side. When the ball is five or more overs old, the bowler decides which side he/she will polish as it is still quite smooth. The opposite side is left to roughen up under normal wear and tear of the game. Air likes rough surfaces and flows quicker around that side. Therefore suction occurs and the ball moves left or right in its flight. Eventually the ball gets very old and the air changes its preference for the side of the ball that it will go faster around.

Normal swing is achieved by keeping one side of the ball polished smooth and shiny, and delivering the ball with the polished side forward, and the seam angled in the direction of desired swing. The out-swinging delivery moves away from the right-handed batsman, while the in-swinger moves in towards him. Normal swing is achieved by maintaining laminar boundary layer air-flow on the shiny side whilst creating turbulent flow on the seam side. These deliveries, particularly the out-swinger, are the bread and butter of opening bowlers who get to use the ball while it is still new.

Despite being widely observed in practice, there is currently no theoretical, or experimental, evidence for humidity having any effect on the amount of swing. Humid air is less dense than dry air—although the difference is

minimal—and so would be expected to induce less swing. Experiments in wind tunnels show no noticeable difference in the amount of swing between dry and humid air, and there is no measureable aerodynamic difference in the state of the ball due to moisture.

There are several possible explanations for late swing—where sideways movement occurs only late in the ball's flight. It is an illusion. The flight path of a ball with a constant sideways-acting force applied to it is parabolic: The amount of the sideways movement naturally increases along the flight path. The ball is initially above the transition speed for turbulent flow on the shiny, non-seam side, but drops below this threshold as it decelerates in flight, particularly after bouncing—initiating late swing. The ball rotates slightly in flight, with the seam becoming angled and thus initiating late swing.

When an old ball swings sharply, and in the opposite direction to that achieved by conventional swing, it is called reverse swing. Pioneered by Sarfraz Nawaz of Pakistan in the 1970s, it was not until the early 1990s that the rest of the world started to understand this method.

Reverse swing is very different to conventional swing. Although the seam is oriented in the same way as for an out-swinger and the action is the same—the rough side of the ball is to the fore, and the ball moves in to the batsman like an in-swinger. Reverse swing is achieved when the ball is bowled very fast. In this case the air flow will become turbulent on both sides before it reaches the seam.

The ball must be 45 or more overs old before it will reverse swing. The rough side is now too rough and the once shiny side has arrived at a degree of roughness that the air prefers to act upon. So without changing the position of the seam, the ball begins to swing in the opposite direction, so called 'reverse' swing. The seam hasn't changed, but the air has changed its preference for the surfaces of the ball.

Before our heads start reverse swinging like the bashed-up ball, let us get quickly to the simple question, when does a ball swing. It swings when the surfaces on different sides of its seam have different textures so that there is a distinct difference in the velocities of flow of air on the two sides.

22

WHEN DOES A CHILD START RECOGNISING FACES?

Right from the moment it sets foot in this world a child starts its learning process. All the senses by then are fairly well developed. They bring in considerable amount of information about the world that surrounds her. The eyes see everything. The ears pick up all kinds of sounds. The nose catches all the aromas, scents and even stinks. The tactile skin lets the baby know of the texture of different substances that come in contact with her. The sense of taste, in comparison, is able to provide only a limited amount of information. That is because, at least in the early part of her life, the baby gets to taste only milk, either that from mother's breast or the bottled variety. Even so, the amount of information is substantial. To analyse that, making some intelligent inferences and storing the gathered data for short term or long term use, is quite a handful of task.

Among all the senses, the sight and sound predominate. Even between the two, eyes perhaps bring in the greatest amount of information. The baby soon learns to make out different shapes and learns to make sense of them. Of these the faces constitute one entity the child sees the most. She gets to see faces of mother, father and some other close relatives. There may be the grandmother, an aunt, an uncle or even an elder sibling. Is the baby able to distinguish between them? Obviously, it does. That is how her own face lights up when she sees the mother or some other favourite relative. And she registers her protest with a loud howl when she encounters an unfriendly or an ugly face.

The point then is when does she acquire this ability. When does the child start recognising different faces? Or, for that matter, when is she able to know which face belongs to a human and which to, say, the family pet? Much as we would like to learn about this from the source itself, the baby is unable to respond and let us know when that proficiency is attained.

Determined to obtain an answer to this vexing question, Robert Fanz conducted some very innovative experiments. He employed for that purpose what is known as the 'preference method'. That method enabled him to find out how children are able to identify various shapes. Suppose two different objects that have similar shapes overall but differ significantly in details are kept in front of tiny tots, would they consider them to be identical? Alternatively, can they pay attention to the differences and make them out to be separate from each other? Which of the two catch their eye? Inferences about cognitive ability of those young ones are based on such an analysis.

Studies conducted on this basis had established that children are able to identify different shapes at a very young age. That has allowed scientists to make some intelligent guesses about the likes and dislikes that get built up at the tender age. It has also made it clear that children are attracted to a human face very early in their life.

Robert Fanz, nonetheless, was not satisfied with that general observation. He wanted to pursue the matter in greater depth and discover how early in life do babies start distinguishing between different faces. He, therefore, prepared two different pictures of a human face. One of these was a realistic one, which meant that, in the picture, different organs that constitute a face were shown at their appropriate positions and also sported their normal shapes and sizes. The other was a surrealistic picture from the Picasso or Salvadore Dali school. Either the position of the different organs were misplaced or their shapes were changed. In some, both were modified. Both the pictures

were now shown to the children. Their preference was noted by observing the time they spent in staring at these pictures.

In the first set of experiments, the pictures were kept steady in one position where the children could easily see them. One month old babies did not show any preference implying that they were unable to distinguish one from the other. In contrast, two month old babies were attracted more towards the realistic picture indicating thereby that they identified it correctly as a representation of the human face. They had acquired that wisdom by the time.

Does it mean that the very young ones were dumb? Not necessarily so, thought Fanz, because even newly born children were seen to ogle at the mother's face showing signs of recognition. That observation prompted him to make a slight alteration in the modus operandi of his experiment. This time he did not keep the pictures steady in one position but kept them moving giving an impression that they were live. Under those circumstances even the one month old babies did show a preference for the realistic picture.

Taking that cue Richard Johnson carried out similar experiments involving children of different ages ranging from one month to five months. He equipped himself with four different pictures. The first of these was the realistic one with all the facial organs in their natural places and also conforming to their natural shapes and sizes. In the second picture, the positions of the organs were maintained but their shapes were altered. The third picture contained normally shaped organs but in altered positions. The organs in the fourth one had neither the natural shapes nor normal positions.

He made one more departure from Fanz's set up. He kept the pictures steady but moved the children in front of them. He noticed that the very young ones spent more time looking at the realistic picture in preference to the rest. Surprisingly, the older ones this time did not show any particular preference. Johnson has thought of two possible explanations for this apparently strange behaviour. One, the older children were not fooled. The static nature of the pictures told them that they were mere caricatures and not real faces. Secondly, by that age children learn to understand different configurations and compositions.

That inference may be debatable. But these sets of experiments have certainly provided more credible answer to the question, when do babies start recognising human faces. They do so very early, even by the first month of their life.

23

WHEN DOES A FLOWER BLOOM?

"Flowers have an expression of countenance as much as men and animals. Some seem to smile; some have a sad expression; some are pensive and diffident; others again are plain, honest and upright, like the broad-faced sunflower and the hollyhock." So said Henry Ward Beecher.

Flowers have attracted not only poets and lovers but almost everyone else too. We associate flowers with all vicissitudes of life. A new birth is celebrated by presentation of a bouquet of flowers to the new parents. A dear departed is given the final salute also with a wreath of flowers. A pink rose is offered to the beloved on Valentine's Day starting a romantic journey. When that reaches a happy milestone the same flowers nicely woven in a garland are exchanged along with vows of matrimony.

These events, momentous as they are in one's lifetime, can occur any time of the year. Yet some flowers or the other are always available at that time. Does it mean that flowers bloom all the time? Then again we see some flowers blossoming in the morning while other prefer the nighttime. The plant *Brahmkamal* is very fussy, blooming only at midnight and that too for a short while. Naturally, one wonders when exactly do they open and provide pleasant balm to our tired eyes.

Carl Linnaeus, the famous botanist who helped classify the living world, had noted that there are three categories of flowers depending on the time of their blooming. There are some that change their opening and closing time according to the weather conditions. These he named

Meteorici. The second group consisted of flowers that changed the times of their opening and closing according to the length of the day. He called them Tropici. All the rest belonged to the group, Equinoctales. They kept fixed timings for their opening and closing irrespective of the prevailing climatic conditions. It is thus clear that we cannot answer the question, when do flowers bloom, with respect to time of the day or the year. One has to look at some other aspects as well.

Specifically, there are two aspects of our obsession with

flowers that we have to think about: First, do they bloom just for us? Second, do the plants in our gardens exist in a vacuum separate from the surrounding environment? The answer to both questions is a resounding 'no'.

The flowering part of a plant contains the sexual reproductive organs. Sexual reproduction allows for variation which helps plants fit in their environment and promotes the long-term survival of the species. Many types of plants reproduce sexually. Angiosperms, or plants which have a covered seed and, often, showy flowers, appear in fossil records some 140 million years ago. There is no coincidence in the fact that the explosion of flowering plants about 100 million years ago corresponds closely with the rise of many of the colonial insects such as ants and bees. The basic fact is that the whole reason for producing those physiologically expensive showy flowers is to attract pollinators which will greatly enhance the plants' chances of successful reproduction.

So there you have it. As much as we may appreciate flowering plants and arrange them in our yard to admire their beauty, they do not flower for us; they flower for the lowly insects. What's more, when the plant goes to seed, its seed form is often designed to attract animals to eat it, thus increasing the chances that the seeds will be dispersed to favourable habitats.

Over 200 years ago, the French biologist, Jean-Baptiste de Lamarck, wrote that the blossom of a European arum lily warmed up during the sequence of blooming. Since then, botanists have recorded significant self-heating in the flowers, inflorescences or cones in several families of plants, including the lotus, many species of arum lilies and a few species of water lilies, Dutchman's pipes, palms, custard apples, magnolias, Illicium, Rafflesia, winter's bark and cycads. These groups are all primitive seed-plants with large, fleshy floral structures that are often associated with beetle, bee or fly pollinators. Heat production is usually thought to enhance the production and dispersal of floral

scents that make the plants more attractive, but in some cases it may prevent freezing of the plant or be a reward to insects by keeping them warm in floral chambers where they may remain overnight.

Some species, such as the arum lilies, are so intensely thermogenic that their flowers can increase up to 35°C above the surroundings. For example, in Brazil, the inflorescence of *Philodendron selloum* is capable of warming to over 40°C when the ambient temperatures are close to freezing. Skunk cabbage, *Symplocarpus foetidus*, in north-eastern U.S.A. and Canada, can maintain temperatures above 15°C when the air temperature drops to –15°C, and it often melts the snow around the plant.

Heat production occurs by rapid respiration in the thermogenic cells of the flowers. In most thermogenic species studied so far, the substrate for respiration is starch, often imported from other parts of the plant, but in *P. selloum*, the substrate is lipid that is stored in the florets prior to blooming. Analysis of heat production by direct calorimetry and respirometry shows that all of the energy in the substrates ends up as heat. Although there is the possibility of some energy going into phosphorylation of Adenosine diphosphate (ADP) or into synthesis of floral structures, this appears to be negligible.

All these preparations by the plant are aimed at but one steady goal. All the apparatus are kept in readiness to attract the insect pollinators that assist in the sexual reproduction of the plant. Naturally, they time their blooming to suit the insect midwives that assist their reproductive activities.

Now we are perhaps in a better position to answer the question: When does a flower bloom? It does so when the parent plant is ready for reproduction. Different flowers bloom at different times of the year and also at different times of day. The flower blooms when the conditions are right for it to attract the insects that help in fertilising the flowers.

24

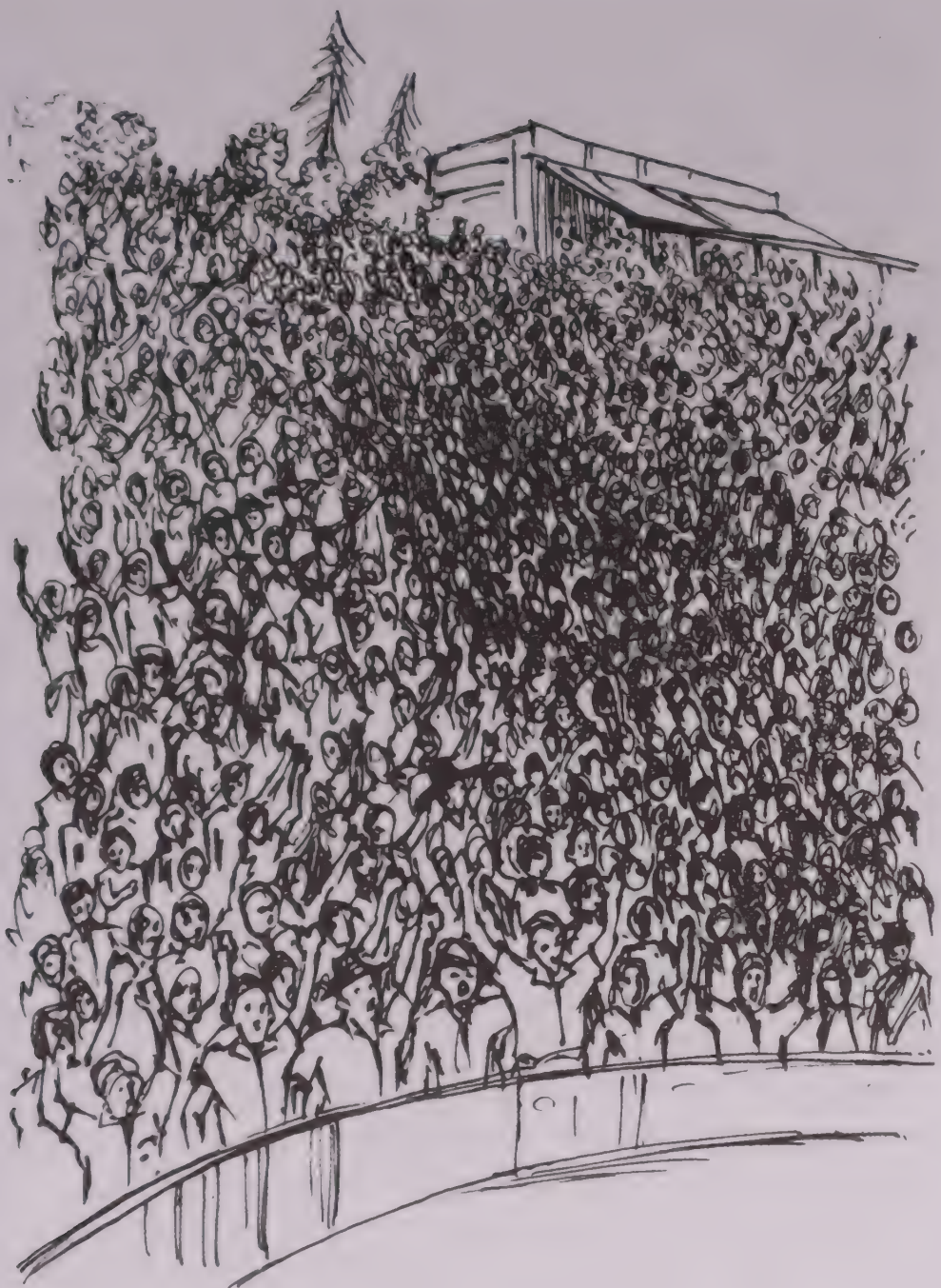
WHEN DOES A MEXICAN WAVE ERUPT?

It is great fun to watch. And even greater fun to participate. A Mexican wave is a typical pattern of behaviour of crowds gathered in a sports arena. The match is in progress. Suddenly a section of spectators gets up and starts waving their arms overhead. No sooner than this section has sat down, that the neighbouring group gets up and does the same. And before one can shout 'Howzzat' one finds that the pattern goes round the entire stadium. Those outside, say those glued to the idiot box at home, can see this beautifully rhythmic and synchronised movement rolling through the audience. To these outside viewers of this crazy but delightful phenomenon it appears as if a wave is passing through the throng of people.

This behavioural curiosity was first noticed at the World Cup Soccer carnival held in Mexico in 1986. That is where the term originated, though in local parlance it is also known as 'La ola'. Since then, however, the particular crowd behaviour has not been restricted to Mexico. Sports fans all over the world have been seen to be bitten by the bug.

This wave is built around a coordinated sequence of actions taken by the members of the audience, in which a group of spectators lying along a radial line extending outward from the sport field, all stand up and raise their arms, then return to a normal seated posture again as the adjacent group of spectators takes its turn to stand up.

The "wave" of standing members travels rapidly through the audience, even though individual audience



members never move away from their seats. In many large arenas the audience is seated in a circular arrangement all the way around the sports field, and so the wave is able to travel continuously around the arena.

So far the wave has amused participants and idle watchers alike. TV commentators draw everyone's attention towards it whenever the wave moves through the crowds. Yet, those entrusted with the job of maintaining peace and decorum at such events have been somewhat anxious about it. 'Would it stop being a pastime and turn into a potentially dangerous disturbance?', they wonder. That is why they have been dying to know when does such a wave erupt. The question has equally captivated scientists too, albeit for a different reason. Interest of those studying mass psychology can perhaps be understandable. But now physicists are also fascinated by the problem. They think that it is yet another situation where tenets of statistical mechanics could be applicable.

Hungarian researcher, Tamas Vicsek, thought of applying principles of statistical physics to unravel this mystic pattern of behaviour. His line of reasoning was as exciting as the wave itself. The behaviour of a single atom or molecule in a cloud of gas is unpredictable. But using statistical techniques, the behaviour of the gas as a whole entity can be deciphered with a great degree of accuracy. This observation was later formalised in the kinetic theory of gases. The same argument was later extrapolated by the eminent Indian scientist, Satyendra Nath Bose, to atoms of other elements as also to fundamental particles that are constituents of atoms. This ingenious idea so captivated the great Einstein that he developed it further to give birth to what is known today as the Bose-Einstein Statistics.

Vicsek wanted to extend the scope of these techniques wider to include what he calls excitable media. This latter term describes a group of individual units that are coupled with each other and can pass on signals to each other. Waves of activity can move across these systems, and are initiated by a trigger over a certain threshold.

One example of "excitable media" is the dry trees and dry litter in a forest. This particular theory of "excitable media" describes how a forest fire starts, and then spreads.

Another is the set of muscles in the heart tissue. A current carried by sodium and potassium ions in one muscle cell moves to neighbouring cells to generate heart contractions.

Vicsek and his colleagues thought that crowds watching a sporting event constitute just such an exciting medium. Each individual in the crowd was, therefore, considered as an excitable unit, and the signal being passed to one another was to stand and wave. The Mexican Wave was the wave activity, and the trigger to begin the wave was a group of active people jumping up and down with their hands in the air.

Armed with these thoughts Vicsek examined the video tapes of fourteen Mexican Waves in stadiums containing at least 50,000 people. It was found that between 25 and 35 people were needed to get the wave going. "It is generated by no more than a few dozen people standing up simultaneously and subsequently it expands through the entire crowd as it acquires a stable, near-linear shape," Vicsek said. The probability of triggering a wave increased with the number of people jumping up and down in the trigger group. To put it more simply, no matter how red in the face you get, you can't start a Mexican Wave by jumping up and down on your own.

The team of scientists also found that the wave usually travelled in a clockwise fashion. In other words, it spread from one person to the next person on their left. Why it should acquire such a directional characteristic is not yet clear. The speed at which the wave moved could also be ascertained from these studies. The wave typically moves at a speed of about 12 meters or 20 seats per second. The normal width of the wave is about 6 to 12 meters or 15 seats.

Thus one main prerequisite for the eruption of the wave became clear. It should have a critical mass of a couple of dozens of spectators to initiate the wave. A group of people less than that trying to ignite such a wave would usually be unsuccessful. The wave may get going but would soon

abort and die down.

But the second requirement is more important. The fare being dished out in front of such a crowd should not be all exciting. There have to be some dull moments in between when the bored fans find this as an exciting way of entertaining themselves. The wave would find it difficult to get going during the slog overs of a one-day international game. Obviously, when the game is very absorbing one's attention is totally riveted to the action on the stretch of green in front of him. He does not want any diversion when a Dhoni is belting everything in sight to high heavens or a Beckham is bending it like no one else. The spectator thus has no time to notice what his or her neighbour is up to. So the one major condition of an excitable medium, that some signal should pass from one constituent of the medium to the next, is not fulfilled. The medium is there but it cannot get excited.

So when does a Mexican Wave erupt? It does so when the game has become boring and there are at least a couple of dozen fans sitting close together, who want an alternative to yawning loudly.

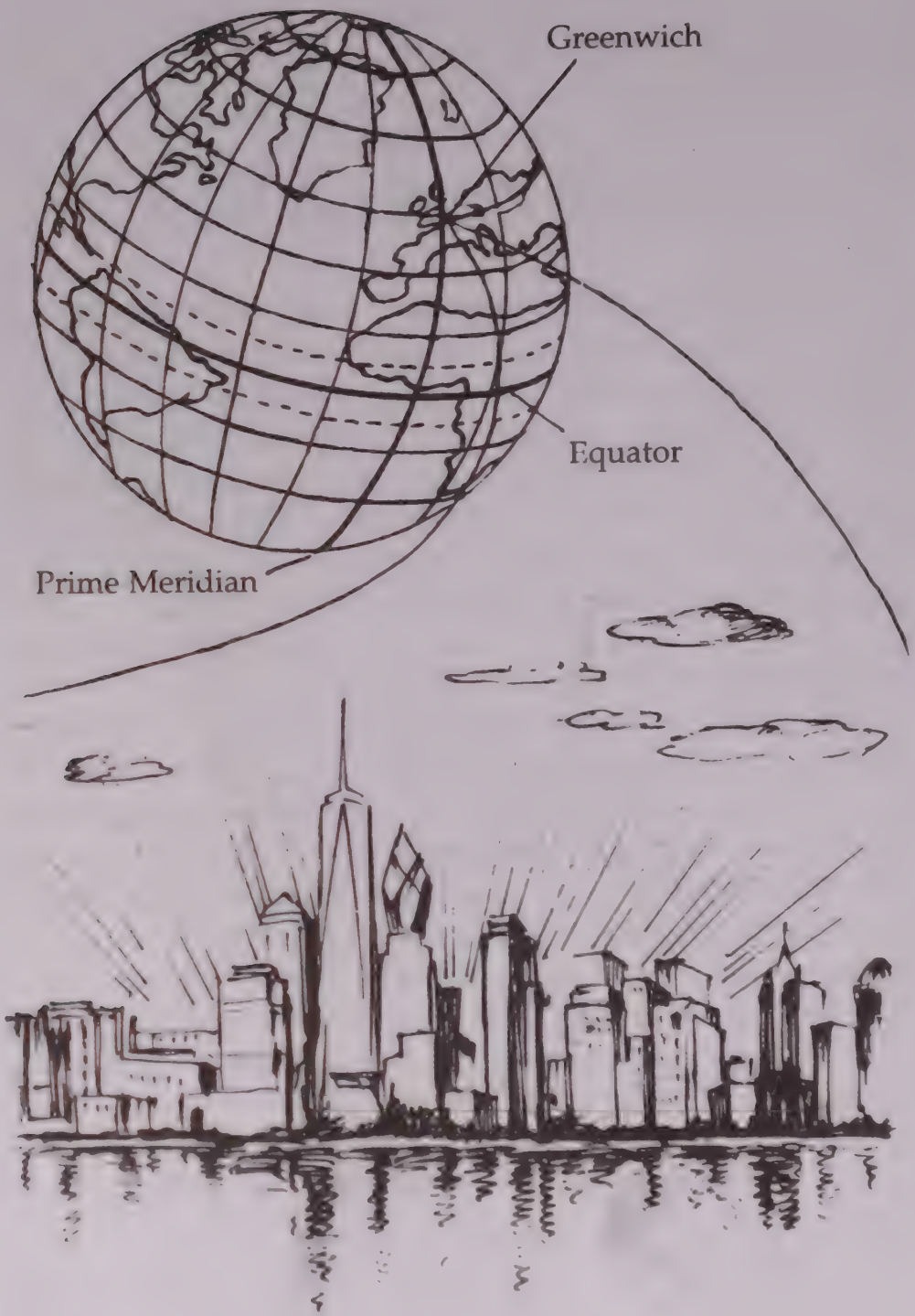
25

WHEN DOES A NEW DAY BEGIN?

Though the question appears very innocuous, there is no easy answer to it. That is because there is no universally accepted definition of the 'beginning' of a new day. In most of the western world, midnight is the hour for the transition from one day to another. Those who subscribe to semitic religions, like Islam or Judaism, believe that sunset marks the end of one day and commencement of a new one. Indians of Hindu faith accord that distinction to sunrise or *Brahmamuhurta*, instead. For many, the first ray of sunlight marks the beginning of a new day.

The difficulties are further compounded due to simultaneous existence of universal time and local time. If we stick to the universal standard time then without doubt the new day will make its beginning at Greenwich. At the stroke of midnight the curtain will be brought down on the dying day. It would, undoubtedly, be night there. So there will be no question of seeing the first light of the new day. According to the western philosophy, that would be the moment a new day would begin. But for those in India, the new day would not have arrived; neither at Greenwich where it would be another few hours before the Sun would get to show up, nor anywhere in India since even there sunrise would be a good half to one hour away.

But at the precise moment when the new day makes its first appearance at Greenwich, the Sun will be ready to peek over the eastern horizon all over the longitude that passes through the Nicobar islands. That particular longitude passes to the north through parts of Myanmar


Greenwich
Equator
Prime Meridian

and Thailand over to large tracks of China, then on to Outer Mongolia and further on to Siberia touching parts of the Arctic. To the south of Nicobar is only the Indian Ocean. So the Sun will grace with its inaugural presence all that territory. At all those locations a new day would have arrived irrespective of which philosophies, oriental or occidental, you subscribe to. The twain would meet there.

That would be the case should you opt in favour of the universal standard time as your system of reference. On the other hand, one could go in for the local time. In that case, midnight would occur at different times at different places. To the east of Greenwich that hour would have passed quite some time ago. The place where it would occur the earliest would be the International Date Line.

Even the first sunrise, per force, will take place on the International Date Line. But that line passes mainly through high seas. There is no inhabited place anywhere. One would have to take a cruise ship perhaps to go the spot to set eyes on that first light. Further south, the line does pass through parts of the Antarctica. There is land there as also some permanent research stations of few countries, including India. But during December it is summer-time there. So the Sun is always shining in the sky. It does not set, nor does it rise. One cannot, therefore, assign any particular ray as the last light or the first light.

If one has to look diligently for an inhabited and land bound place where the first sunrise is to take place, one will have to take off for the Chatham islands belonging to New Zealand. The Kahuatara point in the Pitt islands would be the ideal spot for the purpose. There the Sun will rise at 40 minutes past 4 O'clock, local time. Of course at that moment it will still be the older day at Greenwich, and hence, the new day would not have commenced according to the universal standard time.

The Kiribati Islands have added to the confusion. Parts of these islands stretch to the east as far as the 150 degrees longitude. That is a full 30 degrees east of the International

Date Line. That would have given rise to the problem of having two different dates in different parts of the island. To avoid the ensuing complications, the line was pushed—in 1995—to the east around the islands, placing entire Kiribati to the west of the line. Still it could vie for the honour of being the first to watch the Sun come up on a new day.

With that confusion, how can one give an unequivocal answer to the question, when does a new day begin?

26

WHEN DOES A POPCORN POP?

Popcorn has come to be associated with seeing a movie. So much so that one does not get the feeling of having seen a film unless one has downed a bumper carton of popcorn. In fact, the ticket halls of multiplex movie halls can be distinguished by the aroma of fresh popcorn. The smell of popcorn popping is one that arouses the senses of both young and old, and makes the mouth water for a tasty handful. It makes a cold day a little cosier and a movie a little more enjoyable. Just about everything is better with popcorn and almost everyone loves it. If you want to make instant friends, make a batch of popcorn, and walk through a crowded room! It is one of the most beloved snacks of all time. But where did it come from and how does it pop?

No one knows exactly where popcorn came from or when it was first popped. But archaeologists have been "hot" on the popcorn trail, and they have found popcorn in some most unusual places. One such place was the tombs on the east coast of Peru where they found grains of popcorn that were a 1,000 years old. These grains were so well preserved that they still popped! Ears of popcorn were also found in the Bat Cave of West Central New Mexico that were nearly 5,600 years old. One of the oldest finds of popcorn was made in Mexico City where 80,000-year-old fossilised corn pollen was found buried 200 feet below the city!

Archaeologists believe that popcorn originated in Mexico, but they know that it was grown in China, Sumatra, and India years before Columbus visited America! By the

time Columbus arrived in 1492, popcorn was widespread throughout the North and South America and was enjoyed by most Native American tribes. The natives of the West Indies even tried to sell popcorn to Columbus and his crew, but it wasn't until the first Thanksgiving Feast at Plymouth, Massachusetts that the English colonists were introduced to popcorn. As a gift for the celebration, Quadequina, brother of the Wampanoag chief, Massasoit, brought a deerskin

bag of popped corn. He certainly understood how to make friends fast!

According to Paul Mangelsdorf, Harvard popcorn researcher, "All races of wild corn were popcorns, their kernels small and flinty in texture, almost impossible to chew, and difficult to grind".

Popcorn is an ancient type of corn that contains a hard, glassy (or "vitreous") type of starch on the outside, and a softer, "floury" starch on the inside. In fact, it is probable that popcorn was the original type of corn, and that the first human use of corn grain as a food item occurred when people realised that when they parched this grain, a formerly hard kernel became soft and edible.

Popcorn, a cereal grain like wheat or oats, is about three-fourths carbohydrate in the form of starch, with smaller amounts of protein, fat, minerals, and water. The water plays a critical role in the popping process. When heated, the moisture inside the kernel turns into steam. As the pressure increases, the starch expands and the kernel explodes. We like popped corn that is large and tender. This requires just the right amount of water in each kernel. Farmers harvest popcorn when the moisture content is 16 to 19 per cent by mass. To ensure maximum popping expansion, the corn is then carefully cured or dried until the moisture content reaches 13 to 14 per cent by mass.

Like other cereals, popcorn kernels consist of three main parts: the pericarp, the hull or outer covering; the germ, the part that sprouts; and the endosperm, the starch that expands. Popcorn acts the way it does because of the special construction of the pericarp and the microscopic structure of the endosperm.

Popcorn has an extra strong pericarp. This tough, protective layer acts like a seal, holding in the steam until the pressure builds up high enough and the kernel explodes. If the pericarp has been cut or cracked during processing, the steam will be vented and the kernel will not pop properly.

Corn has two kinds of endosperm—translucent and opaque—which are named according to their appearance. The expansion, or popping, takes place in the tightly packed translucent endosperm. Popcorn contains mostly translucent endosperm, which is better at popping.

Before you start cooking popcorn, the pressure inside and outside the kernel is the same. As the kernel heats, the moisture turns to steam, and the internal pressure of the kernel rises. When the temperature inside the kernel climbs above 100°C, you might expect that all the water would turn to steam. In fact, only a small amount vaporises because the tough pericarp acts like a pressure cooker. The high-pressure steam penetrates the starch granules and transforms them into hot, gelatinised globules. Finally at about 175°C, when the pressure inside the kernel is about 9 Atmospheres, the pericarp ruptures.

The steam and superheated water, now surrounded by normal-pressure air, become the driving force that expands the kernel. The gelatinised starch granules do not explode, but expand into thin, jelly-like bubbles. Neighbouring bubbles fuse together and solidify, forming a three-dimensional network much like a sink full of soapsuds. This is the white fluffy solid we eat. The moisture content of the kernel is now about 1 to 2 per cent by mass, and the popcorn is transformed into a tender, fluffy morsel.

So, the popcorn pops when the 'pressure cooker' inside its pericarp explodes. Normally the internal pressure reaches this level when the temperature climbs to 175°C.

27

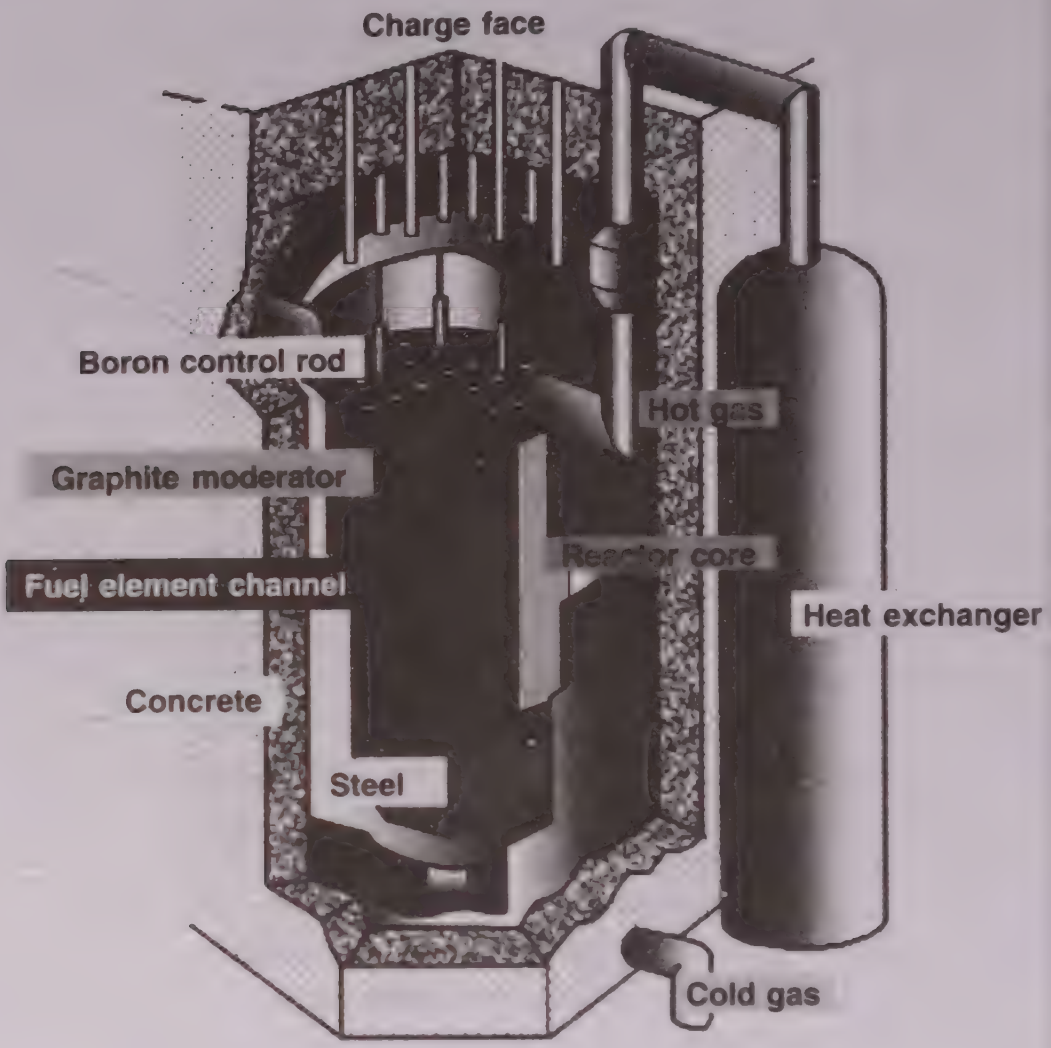
WHEN DOES A REACTOR BECOME CRITICAL?

Whenever a person is seriously ill and the doctors treating him are unable to predict when he will get well, if at all, that person is said to be in a critical condition. The word critical has thus come to be associated with terminal illness. That is why whenever one hears of a reactor going critical one starts getting apprehensive. The images of Hiroshima and Nagasaki immediately start appearing before one's eyes.

But that perception is erroneous. The word critical is not a harbinger of death when applied to an atomic reactor. On the contrary it heralds the coming to life of that reactor.

A nuclear reactor is dependent on a chain reaction in which atoms of the nuclear fuel material undergo fission in rapid succession. The splitting of one atom gives rise to conditions that trigger the splitting of another, that of the third and so on. Not all elements possess this property of undergoing fission. But Uranium, the heaviest of all natural elements, is one such fissile material.

In nature Uranium is found in three different forms. The chemical properties of all the three forms are identical. Put differently, they can replace one another in any chemical reaction they undergo. However, their physical properties are not the same. For example, they differ in their atomic weights. The lightest among them has an atomic weight of 233. This form, or isotope, to give it its scientific name, has 92 protons and 141 neutrons in its nucleus. A slightly heavier isotope with an atomic weight of 235 has the same 92 protons but 143 neutrons. The heaviest one with the atomic weight



of 238 has 146 neutrons. They also differ in their ability to undergo fission. The one with the atomic weight of 235 is the best at that but the heaviest having an atomic weight of 238 is not as efficient.

With its heavy load of neutrons, these atoms are already quite unstable. They try to shed this additional burden by trying to get rid of some of their nuclear baggage by emitting radioactive rays. But when another neutron hits the atom and gains entry into its nucleus that turns out to be the proverbial last straw that breaks the camel's back. The atom cannot quell the internal turmoil anymore and explodes.

This splitting of the atom gives rise to two, much lighter, elements—Barium and Krypton. Simultaneously, it also emits large amount of energy that was engaged in keeping all the nuclear particles together. More importantly, about 2.3 neutrons also emerge out of this reaction. They can now bombard another 2.3 atoms to break them open giving rise to yet another burst of 2.3 neutrons each. A chain reaction is, thus, set in motion.

Every incident of nuclear fission results in the emission of large amount of energy. If this chain reaction is allowed to proceed naturally, more and more atoms would undergo fission at every step leading to an explosion. That would be disastrous. What is needed is a mechanism that allows the chain reaction to proceed in a controlled fashion. That can be achieved only if one ensures that every fission event would give rise to precisely one more neutron. That would make certain of uninterrupted continuation of the chain reaction without causing an explosion. That is the principle on which an atomic reactor functions.

A nuclear reactor consists of an assembly of nuclear fuel surrounded by elements of a material that acts as a neutron moderator. This material is more hungry for neutrons than the fuel. So it can help in absorbing the extra neutrons preventing them from hitting atoms of the fuel. It also slows down the neutrons thus enhancing their ability to cause fission. The geometry of the fuel assembly also ensures that some of the 2.3 neutrons produced at every step of a fission reaction escape to the outside, thereby avoiding collision with an atom of the fuel. The objective is to achieve a situation where only one of the 2.3 neutrons given out survives to hit precisely one more fissile atom. Thus a runaway chain reaction is averted even as it proceeds in a very disciplined manner.

Water, graphite, cadmium or zirconium hydride are some of the materials that can act as neutron moderators. The reactor is also provided with control rods that can ensure shutting off totally of the chain reaction should such

need arise. There might be some other materials also in the reactor assembly.

In a nuclear reactor, most fission events are caused by neutrons impacting nuclear fuel. Hence, the power output, and neutron production, of a nuclear reactor depends on the number of neutrons that are already in the core from previous fissions, and on the expected value of how many fissions will occur as a result of each neutron, before the neutron is absorbed or lost. If the rate of production of new neutrons from the fission in an assembly of nuclear fuel, the "core", is less than the rate of loss from absorption or escape, then the core is sub-critical and will not support a self-sustaining chain reaction. If the rate of production exceeds the rate of loss, then the core is supercritical and the amount of neutrons produced will grow exponentially.

One can describe the conditions inside a reactor with a complex set of mathematical equations aimed at determining the status of neutrons and the probability of a fission event taking place at any instant. This yields a constant named by the scientists as alpha (α). This is nothing but the expected number of neutrons, after one average neutron lifetime has elapsed.

If α is positive, then the core is supercritical and the rate of neutron production will grow exponentially until some other effect stops the growth.

If α is negative, then the core is sub-critical, and the number of free neutrons in the core will shrink exponentially until it reaches an equilibrium at zero or the background level from spontaneous fission.

If α is exactly zero, then the reactor is critical and its output does not vary in time. When that happens the nuclear furnace comes to life giving out energy in an assured manner.

So when does a reactor become critical? It does when it can support a self-sustained controlled fission chain reaction.

28

WHEN DOES A STAR DIE?

Which star is one talking about? The movie star? Or the little one which goes on twinkling up above the world so high? The latter, of course! For the other one is a mere mortal like the rest of us. Does that mean that the diamond in the sky too is mortal? That is true. There is no better or more accurate statement of this fact than the oft-recited *shloka* from the *Bhagvad Gita*:

Jatasya hi dhruvo mrityu
Dhruvam janama mrutasya cha

Everything that is born is destined to die only to take birth again. This has been aptly proved to be true in the case of those celestial bodies.

The life history of a star is extremely fascinating, although scientists are acutely aware that our knowledge of it is rather paltry. Whatever little we do know, we owe it in no small measure to the Indian-born Nobel laureate Subrahmanyam Chandrasekhar.

There is now a general agreement that the universe was born out of 'Big Bang'—an explosion of gargantuan proportion. Some 100 million years later, the primordial gas, which was thrown about as a result of this outburst gave rise to galaxies. These originated out of the randomly colliding gas molecules. Gravitational attraction could coalesce and keep together at least some of these molecules thrown against each other. Thus, a stable cloud of gas which did not disintegrate further was formed.

Such condensates constitute an embryonic protostar. The nucleus can exercise gravitational pull on the surrounding matter to grow bigger. But as it does so the intense gravitational attraction of the centre leads matter on the periphery to collapse inwards. This increases the density at the centre. This kind of a chain reaction increases the rate at which particles move inwards generating intense heat.

The shrinking of an embryonic star is mind boggling. For example, our Sun has an estimated diameter of some 1.4 million km. But astronomers believe that during its embryonic stages its diameter was as large as trillions of kilometres. Obviously then the rise in the temperature of its core when such a compression takes place is equally dramatic.

When the temperature reaches about 10 million degrees, the nuclei of hydrogen gas collide together with such great force that the electrical repulsion that keeps them apart is easily overcome. This is the process of fusion by which hydrogen is converted into the next heavier chemical element—helium.

When protons and neutrons come together to form an atomic nucleus, the combination is more stable. However, it contains less mass than the combined mass of the constituent particles. The 'missing' mass is converted into energy either as heat or light and is radiated away.

Likewise, when hydrogen nuclei are thrown together and get converted into helium nuclei, some mass is converted into radiant energy. A thousand tons of hydrogen are converted into only 993 tons of helium and seven tons of mass is transformed into energy. This is the process by which stars like our Sun radiate energy.

This commissioning of the stellar furnaces infuse 'life' into it. A star is born. The event also stabilises it. For the inward gravitational pull is now counterbalanced by the outward pressure generated by the fusion reactors at the centre. So, further collapse of the star is thwarted.

But the hydrogen fuel that stokes these furnaces is not unlimited. Sooner or later it gets exhausted. When that happens, the furnaces shut down, but only for a while. Because with their shutting down the outward pressure which was preventing further shrinkage of the star also ceases to act. Consequently, the density of the central core rises with the concomitant increase in its temperature. This goes on till the temperature ascends to a level where helium nuclei can undergo fusion to form the next heavier element, carbon. The 'missing' mass once again metamorphoses into energy. The stellar furnaces are back in harness bringing stability to the star.

In a time period shorter than it takes hydrogen to be completely used up, the helium supply too dries up. The fusion reactors shut down one more time until the gravitational collapse raises the temperature to a level where carbon nuclei can fuse. And this phenomenon keeps on repeating with the core of the star being successively made up of such heavier and heavier elements like silicon, sulphur, argon, calcium and finally iron. Iron is the most tightly bound element. So it cannot be induced to undergo fusion reaction. The thermonuclear reactors sustaining the star's life down their shutters for good.

With the closing down of the fusion reactors there is no more outward pressure to resist the gravitational pull inwards. Further collapse, therefore, occurs very rapidly. The tremendous amount of gravitational energy that is generated sends massive shock waves towards the periphery of the star causing it to explode violently. It becomes a supernova. The violence of this explosive event can be so great that the luminosity of the star increases thousand or even million fold. Under those circumstances, a single star can produce, albeit briefly, more light than an entire galaxy. It is a spectacular sight indeed. Even in death the star shines brightly.

What happens to the star after such a scintillating death is equally fascinating. Basically, it depends on the mass of

the star. The very hot, dense, small core may become a white dwarf. If our Sun were to collapse and become a white dwarf its diameter will be reduced to a mere 16,000 km.

If the gravitational collapse is more severe, the core may get converted into a neutron star which might emit radio pulses. There is yet another possibility. The gravitational collapse may be so intense that, as Einstein has predicted, even light will not be able to escape from it. What comes into existence then is a black hole.

But that is all later, after it has died. But when does it die? When the fuel for its ever hungry furnaces is no longer available. To put it in a more succinct manner, when the core is made up totally of iron.

29

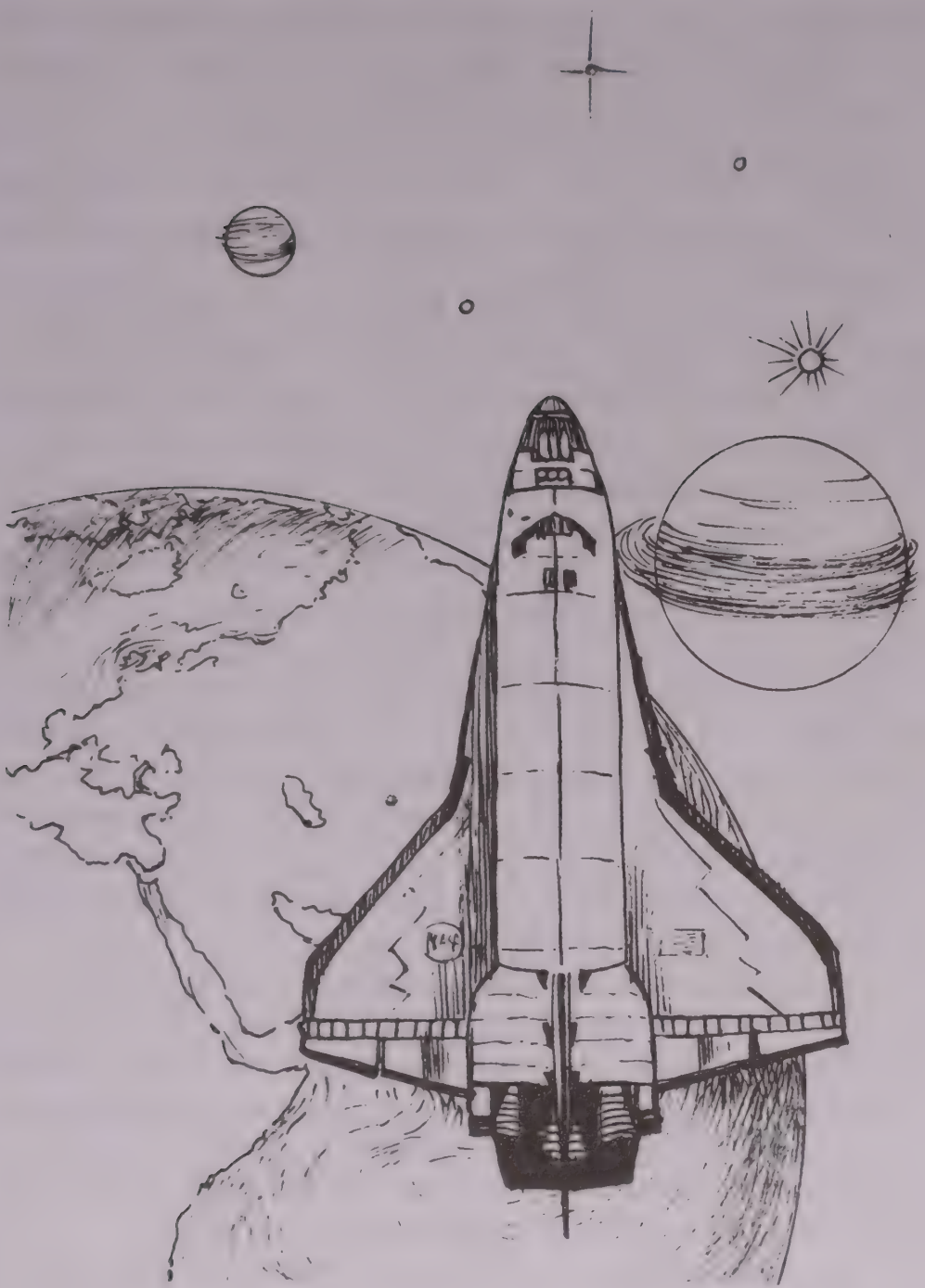
WHEN DOES AN OBJECT ESCAPE GRAVITATIONAL PULL?

Never! That would be your immediate response. That is because you have heard that the gravitational field never reaches a magnitude of zero. It may become small, infinitesimally small, yet never zero. That is why one talks in terms of micro gravity but not zero gravity.

But the operative word here is 'escape'. The object may continue to experience the gravitational attraction of, say, the earth, yet it may also gather enough momentum to get away from its pull and escape into outer space. In fact, this is what all the spacecrafts and artificial satellites accomplish with uncanny regularity. This is because they are propelled with such velocity that they are able to get away despite that gravitational influence.

The gravitational force is one of the fundamental forces and has been with us ever since the universe was born. As a matter of fact it is this force which made it possible for the universe to come into being and has been sustaining it ever since. If the universe is orderly it is in no small measure due to this force holding it together.

However, mankind was blissfully unaware of its existence. It was not as if it had not experienced it or observed phenomena that arose as a result of the working of this force. But it had not inferred that it is this force that announces its existence through such every day phenomena like falling to the ground of ripe fruit. Isaac Newton was the first to reason it out and introduce the world to its nature and the mode of its working. He also deciphered



that the magnitude of gravitational attraction depended on the masses of the two objects and the distance between them. However, the exact relationships had different characteristics. While the magnitude of the attractive pull increased with the mass, it decreased with the distance. In other words, the greater the mass of a body the higher was the strength of attraction.

In contrast, the greater the distance between two bodies the weaker was the attraction between them. In fact the force of attraction decreased as the square of the distance between the two bodies increased. If the distance increased two-fold, the strength of the attractive force decreased four-fold. So, as an object reaches greater heights the pull that the earth exerts on it, dwindles. Still, it continues to pull the object down. If the object is moving with some velocity then it acquires a certain force. This force can counterbalance the force of attraction. As the velocity of the object increases the force with which it is moving also increases. If that force is greater than that required to overcome the gravitational pull, then it can escape into outer space. The minimum velocity with which an object should move to escape the gravitational pull experienced by an object is called the "escape velocity".

If a spacecraft is launched from a pad on the surface of the earth with this speed or greater, it will escape the Earth's gravitational field. The escape velocity can be calculated from the Earth's mass, its radius, and Newton's gravitational constant 'G'. It is assumed for that formula that air resistance doesn't slow down the spacecraft. For the Earth, this speed is 11,200 m per sec, or about 40,000 km per hour.

No, the spacecraft will not continue at that speed. Gravity will constantly pull the spacecraft towards the Earth and slow it down. If the spacecraft is launched so that it is going faster than the escape velocity, it will still continue to pull away from the Earth at a slower speed long after it has climbed out of the Earth's gravitational field. If it is launched with a velocity equal to the escape velocity, it will slow

down and may be just able to avoid falling back. It will continue farther out, but always move slowly. If the craft is launched at a speed lower than the escape velocity, it will never be able to enter the outer space. It will fall back to the Earth.

Of course, one could then ask a related question: How far does earth's gravity extend? Supposedly, a very similar question occurred to Isaac Newton in 1666, possibly when he saw an apple fall from a tree. The apple was attracted to the Earth, which made it fall. How far from Earth did this pull extend? In particular, the Moon must also be attracted to the Earth. Otherwise it would wander off into space. Did this same force extend all the way to the moon, and keep it in its orbit?

Newton's answer was a "Yes." Assuming that the force decreased with distance r like r-squared, he calculated the orbital period the Moon should have, and came out with the correct number.

Since the masses of different planets and their moons are different, their gravitational pulls are also different. Consequently, the escape velocity for these celestial spheres would also be different. For example, the moon's gravity is only one-sixth of that of the earth. So the escape velocity for an object to get away from the moon's attraction would be correspondingly lower.

So when does an object escape gravitational pull? When it is moving with a velocity that exceeds the escape velocity.

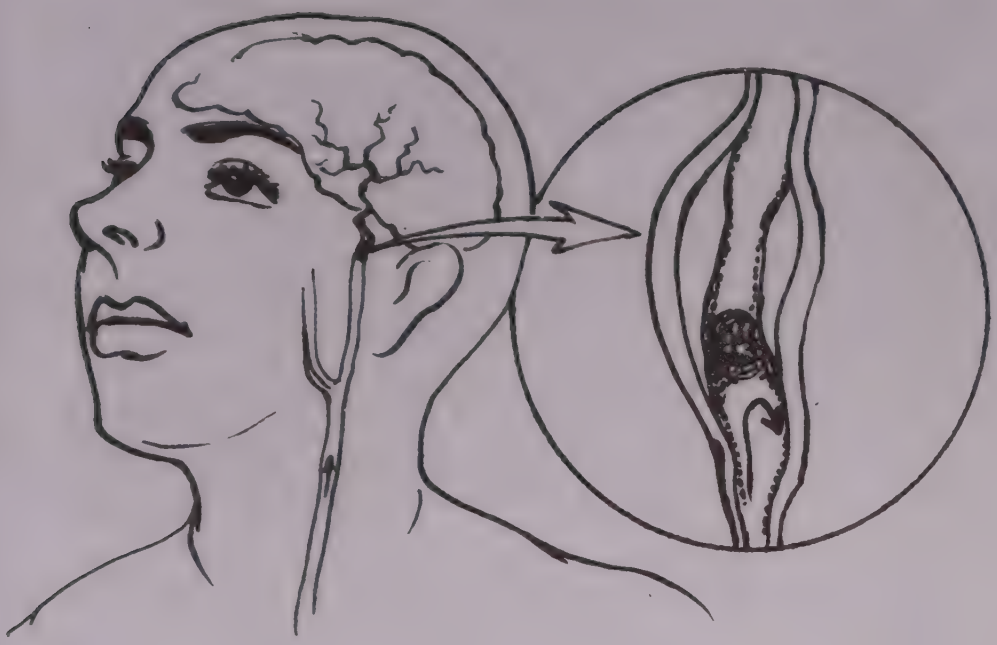
30

WHEN DOES BLOOD CLOT?

Whenever a blood vessel anywhere in the body gets cut, the blood inside starts oozing out. The cut may occur accidentally. On the other hand, it might be the result of a deliberate action taken during surgery. Whatever may be the cause one starts bleeding as a consequence. However, the body cannot stand excessive blood loss. So measures have to be taken to stem the flow.

Surgeons achieve this by immediately putting clamps on the cut vessel. But when the bleeding arises out of an accident and there are no doctors to take prompt action, what happens? Does one continue to bleed to death? Hardly! Because Nature intervenes at such times. The blood clots and the resulting clump seals the open blood vessel. The question that naturally arises in one's mind is: When does this clot formation take place? Does it happen before it is too late? Obviously it does. Otherwise any cut, however insignificant, would have turned fatal. Even so, one would like to know when the blood clots.

Clotting of blood is a long process involving a series of biochemical reactions taking place in a specific sequence. Several components of blood take part in this chain of events. Availability of each of these components is essential for the orderly progression of events leading to clotting of blood. If any one of these factors is not present or is not functioning properly, it can hinder the process of clotting of blood. As a result the blood may not clot at all. This would cause extensive haemorrhage that is detrimental to the health of the individual. Alternatively, there may be



excessive clotting which can also lead to some serious health problems.

Blood contains basically three types of cells, the erythrocytes or red blood cells, the leucocytes or white blood cells and the platelets. The red blood cells essentially carry and supply oxygen to different parts of the body. The white blood cells are engaged in defending the body against invasion of disease-bearing organisms. Platelets play a major role in the clotting of blood.

These cells float in a fluid called plasma. The plasma also contains a large number of proteins with varied responsibilities. Among these, there are certain elements known as clotting factors. In tandem with the platelets the clotting factors act to form blood clots.

Platelets, also called thrombocytes, are tiny oval-shaped cells made in the bone marrow. When a blood vessel breaks, platelets gather in the area and help seal off the leak. Platelets survive only about 9 days in the bloodstream and are constantly being replaced by new cells. Although platelets alone can plug small blood vessel leaks and temporarily

stop or slow bleeding, the action of clotting factors is needed to produce a strong, stable clot.

Platelets and clotting factors work together to form solid lumps to seal leaks, wounds, cuts, and scratches and prevent bleeding inside and on the surfaces of our bodies. The process of clotting is like a puzzle with interlocking parts. When the last part is in place, the clot happens. But if even one piece is missing, the rest of them cannot come together to form the sealing clump.

When large blood vessels are severed, or cut, the body may not be able to repair itself through clotting alone. In these cases, dressings or stitches are used to help control bleeding.

Clotting is the solidification of blood in a process known as coagulation. A blood clot consists of a plug of platelets enmeshed in a network of insoluble fibrin. When bleeding occurs, chemical reactions change the surface of the platelet to make it "sticky". Sticky platelets are said to have become "activated". These activated platelets begin adhering to the wall of the blood vessel at the site of bleeding, and within few minutes they form what is called a "white clot."

The thrombin system consists of several blood proteins that become activated when bleeding occurs. When blood vessels are severed or damaged, the enzyme thrombokinase is secreted by the damaged tissues and blood platelets in the bloodstream. Thrombokinase converts prothrombin—which is a soluble protein in the bloodstream—into thrombin. The activated clotting proteins engage in a cascade of chemical reactions that finally produce a substance called fibrin. Fibrin can be thought of as a long, sticky string. Fibrin strands stick to the exposed vessel wall, clumping together and forming a web-like complex of strands. Red blood cells become caught up in the web, and a "red clot" forms. A mature blood clot consists of both platelets and fibrin strands. The strands of fibrin bind the platelets together, and "tighten" the clot to make it stable.

In arteries, the primary clotting mechanism depends on

platelets. In veins, the primary clotting mechanism depends on the thrombin system. But in reality, both platelets and thrombin are involved—to one degree or the other—in all blood clotting.

Blood also possesses an anti-coagulation substance called heparin, which is produced by the liver. Heparin ensures that under normal conditions, blood remains in the fluid state. Consequently, it flows smoothly and no clotting takes place. When thrombokinase is released, it neutralises the action of heparin so that clotting can effectively take place. Plasma contains plasminogen that binds the fibrin molecules in the clot. When the wound has healed, the normal cells would secrete Tissue Plasminogen Activator (TPA) to attach themselves to the clot, converting the plasminogen to plasmin. Plasmin will digest the fibrin and dissolve the clot when the wound has covered up and healed.

Different clotting factors act at different stages of the cascade of reactions leading to the formation of a clot. If any of these factors are adversely affected due to certain hereditary defects, then bleeding disorders can occur. The most common is haemophilia. It is an inherited condition that almost exclusively affects males. It involves lack of a particular clotting factor in the blood. People with severe hemophilia are at risk of excessive bleeding and bruising after dental work, surgery, and trauma. They may experience episodes of life-threatening internal bleeding, even if they haven't been injured.

Haemophilia is also known as the royal disease because it ran through a number of European royal houses. Almost all of those affected were descendents of Queen Victoria. It is inferred that a mutation she harboured was responsible for this condition. She being a woman did not suffer from the disease herself but passed on the mutation to some of her male descendents. Today haemophilia is treated by supplying externally the absent clotting factor.

In contrast, excessive clotting can also occur due to abnormalities in the clotting factors. Clotting factors are

proteins. Their normal function is to ensure that blood does not become too thick or too thin. Nonetheless, under certain circumstances the body becomes more prone to developing blood clots. This can lead to blood clots that can cause harm to heart, lungs, brain or extremities. If a clot forms in such an area it can cause blockage of small blood vessels. In turn, blood may not be supplied in adequate amounts to the crucial organ. More seriously, a piece of the clot may break off and travel through the circulatory system. It can get stuck in the smaller blood vessels that supply blood to the heart, lungs or brain. That can result in a life-threatening situation.

In most cases abnormal clotting does not occur. But when it does, substances that prevent coagulation of blood cells can be given to the patient. These are known as anticoagulants. They may not dissolve the clot already formed, but prevent formation of any more clots.

So, when does blood clot? It does whenever a wound causes bleeding. It is a natural preventive mechanism to ensure that life does not literally flow out of the system.

31

WHEN DOES CEMENT HARDEN?

Well, frankly, this is a wrong question. That is because it is not the cement that hardens but the concrete. Cement is just one of the ingredients of concrete. However, in the colloquial parlance the name of the constituent is used synonymously for that of the product. But really speaking we should be talking about the hardening of concrete rather than cement.

Concrete is a material used in building construction, consisting of a hard, chemically inert particulate substance, known as an aggregate. This is usually made from different types of sand and gravel. The aggregate is bonded together by the paste of cement and water.

Although the cement presently used is of relatively recent origin; the practice of using a bonding material has been in vogue since ancient times. The Assyrians and Babylonians used clay as the bonding substance or cement. The Egyptians used lime and gypsum cement. In 1756, British engineer, John Smeaton made the first modern concrete, or to use its scientific name the hydraulic cement. He used pebbles as a coarse aggregate and mixed it with powdered brick before adding the cement. In 1824, English inventor, Joseph Aspdin invented what is known as Portland Cement. Portland cement is not a brand name, but the generic term for the type of cement used in virtually all concrete, just as stainless is a type of steel and sterling a type of silver. This has remained the dominant cement used in concrete production. Joseph Aspdin created the first true artificial cement by burning ground limestone

and clay together. The burning process changed the chemical properties of the materials and created a stronger cement than what using plain crushed limestone would produce.

The other major part of concrete besides the cement is the aggregate. Aggregates include sand, crushed stone, gravel, slag, ashes, burned shale, and burned clay. Its quality depends upon the size of the particles in the aggregate. The one with smaller particles is called the fine aggregate. It is normally used in making concrete slabs and smooth

surfaces. On the other hand, larger particle size makes coarse aggregate. This is used for massive structures or sections of cement.

Concrete that includes embedded metal is called reinforced concrete. In most cases the embedded material is steel. Such a concrete is also called ferro-concrete. Of late glass fibre is also used in place of steel.

Reinforced concrete was invented by Joseph Monier. He was a Parisian gardener who made garden pots and tubs of concrete reinforced with an iron mesh. Reinforced concrete combines the tensile or bendable strength of metal and the compressional strength of concrete to withstand heavy loads. Joseph Monier exhibited his invention at the Paris Exposition of 1867. Besides his pots and tubs, Joseph Monier promoted reinforced concrete for use in railway ties, pipes, floors, arches, and bridges.

To accord further strength, pre-stressed concrete is prepared. In conventional reinforced concrete, the high tensile strength of steel is combined with concrete's great compressive strength to form a structural material that is strong in both compression and tension. The principle behind pre-stressed concrete is that compressive stresses induced by high-strength steel tendons, in a concrete structure before loads are applied, will balance the tensile stresses imposed in the member during service.

The principle behind pre-stressing can be seen to be employed when a row of books is moved from place to place. Instead of stacking the books vertically and carrying them, the books may be moved in a horizontal position by applying pressure to the books at the end of the row. When sufficient pressure is applied, compressive stresses are induced throughout the entire row, and the whole row can be lifted and carried horizontally at once.

A simpler way to understand this principle is to hold a rubber band between two fingers. If it is held loosely it can easily bend when a load is applied which exerts a downward pressure. If stretched it now becomes taut and resists the

pressure. Consequently it does not yield easily and does not bend.

That is why the reinforcing material is stretched across the casting bed. Usually about 15,000 kg equivalent of tension is applied while concrete is poured all round it. Pre-stressing removes a number of design limitations that conventional concrete places on span and load; and thus permits the building of roofs, floors, bridges, and walls with longer unsupported spans. This allows architects and engineers to design and build lighter and shallower concrete structures without sacrificing strength.

Whichever concrete is used, it needs to harden before it can provide the desired or designed strength. Concrete gets stronger as it gets older. Cement comprises 10 to 15 per cent of the concrete mix, by volume. Through a process called hydration, the cement and water harden and bind the aggregates into a rock-like mass. This hardening process continues for years meaning that concrete gets stronger as it gets older.

So, there is no such thing as a cement sidewalk, or a cement mixer; the proper terms are concrete sidewalk and concrete mixer. The hydration process continues over a long period of time. It happens rapidly at first and slows down as time goes by. To measure the ultimate strength of concrete would require a wait of several years. This would be impractical, so a time period of 28 days was selected by specification writing authorities as the age that all concrete should be tested. At this age, a substantial percentage of the hydration would have taken place.

Curing is one of the most important steps in concrete construction, because proper curing greatly increases concrete strength and durability. Concrete hardens as a result of hydration—the chemical reaction between cement and water. However, hydration occurs only if water is available and if the concrete's temperature stays within a suitable range. During the curing period—from five to seven days after placement for conventional concrete—the

concrete surface needs to be kept moist to permit the hydration process. New concrete can be kept wet with soaking hoses, sprinklers or covered with wet burlap, or can be coated with commercially available curing compounds, which seal in moisture.

Temperature extremes make it difficult to properly cure concrete. On hot days, too much water is lost by evaporation from newly placed concrete. If the temperature drops too close to freezing, hydration slows to nearly a standstill. Under these conditions, concrete ceases to gain strength and other desirable properties. In general, the temperature of new concrete should not be allowed to fall below 10 degrees Celsius during the curing period.

Concrete, like all other materials, will slightly change in volume when it dries out. In typical concrete this change amounts to about 500 parts per million. Translated into dimensions, this is about 1.5 mm in 3 m. That is the reason for putting joints in concrete pavements and floors. They allow the concrete to crack in a neat, straight line at the joint when the volume of the concrete changes due to shrinkage.

So it is not easy to tell when the concrete hardens as the process goes on all the time. The older it gets the more hardened it becomes. Therefore, a very truthful answer to the question would be 'never'. However, one can confidently say that it hardens four weeks after pouring since most of the hardening process is completed by hydration over that period of time.

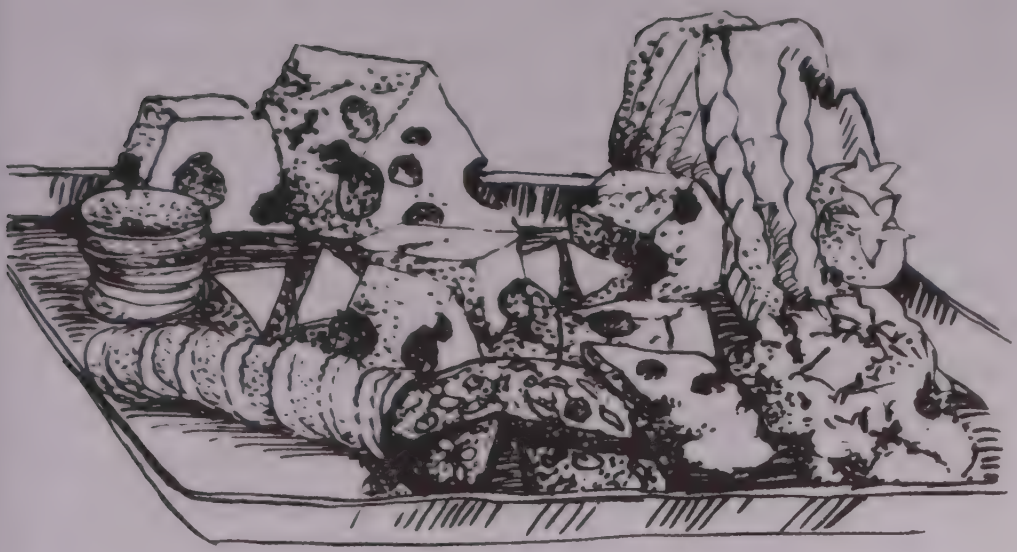
32

WHEN DOES CHEESE 'RUN'?

Let us get one thing clear so that there is no room for confusion whatsoever. One is not talking of Cheese, the secure web information system. This security software may be full of holes like swiss cheese thus fully meriting the sobriquet. Even so, that is not the running topic here. There are other uses of the term cheese. To decipher these, Wikipedia asks one to turn to 'disambiguation'. So without any ambiguity let it be made clear that we are simply looking at that particular food item which is the darling of many and may be anathema to some.

Nonetheless, let us be absolutely clear as to what constitutes cheese before we start grappling with the problem of its running. Cheese is a food made from the curdled milk of cows, goats, sheep, buffalo or other mammals. The milk is curdled using some combination of rennet or rennet substitutes and acidification. Bacteria acidify the milk and play a role in defining the texture and flavour of most cheeses.

There are hundreds of types of cheese produced all over the world. Different styles and flavours of cheese are the result of using different species of bacteria and molds, different levels of milk fat, variations in length of aging, differing processing treatments including cheddaring, pulling, brining, mold wash, and different breeds of cows, sheep, or other mammals. Other factors include animal diet and the addition of flavouring agents such as herbs, spices or wood smoke. Whether or not the milk is pasteurised also affects the flavour.



Then there is the processed cheese. It is a food product made from regular cheese and other unfermented dairy ingredients, plus emulsifiers, extra salt, and food colourings. Many flavours, colours, and textures of processed cheese exist. It has three technical advantages over unprocessed cheese: extended shelf-life; resistance to separation when cooked; and the ability to reuse scraps, trimmings and runoff from other cheesemaking processes.

The chefs and gourmets, however, would not be amused by all this fancy information. They would only be interested in an unambiguous answer to a simple question, when does cheese 'run'. They are right too because the demands of different dishes where cheese is one of the tasty ingredients are quite different. A simple cheese and tomato sandwich requires that the cheese retains its texture and does not melt. On the other hand, if the same sandwich is to be grilled then one expects the cheese to melt but not run. In the latter event the sandwich would become one soggy mess making it unappetising. Yet, when one is making a pizza one wants the cheese not only to melt but run all over the top. And when one is making a cheese kebab one hopes that the cheese cube just grills nicely acquiring an

even tan. It should not run, not even melt. It should just stay put and char uniformly. Naturally, one would like to know when does cheese 'run'.

Scientists have now come to their help. They state that the fat content of a cheese dictates its behaviour on heating. It is partly the high fat content in cheeses such as cheddar that makes them go gooey and stringy when cooked. The fat has a low melting point and runs before the cheese browns. Low-fat cheeses such as cottage cheese will generally not melt so well when heated, but they do change in texture. This is mainly because milk protein, the other main component of cheese, is denatured by heat. The protein in high-fat cheeses denatures too, which is why melted cheddar turns into an unpleasant rubbery lump when it goes cold.

This is not the whole story though, because *Halloumi* cheese which is used in cheese kebabs, while delicious, is not a low-fat cheese. Why is it then that it does not melt and become stringy? That is because *Halloumi* is heated and partially cooked as part of its production process. So changes have already occurred before you cook it. Because of this the cheese retains its texture under the grill. It is already slightly rubbery before cooking, making it excellent to use in kebab. Speaking of this type of texture, another cheese that cooks in a similar way is our own indigenous *paneer*. This works well in *tandoori* kebabs.

So when does cheese 'run'? It does so when its fat content tends to be on the higher side. Quite contrary to human behaviour, isn't it? A human shies away from running when the fat content is on the higher side. But then humans are known to be quite queer.

33

WHEN DOES IT RAIN?

We hold a love-hate relationship with rain. Rain provides us with fresh and running water so essential to life. In those parts of the world that are not endowed with perennial rain, arrival of rain is an eagerly awaited event. Over the Indian sub-continent where it is a seasonal occurrence, the soil scorched and river beds dried out by intense summer heat make people look upwards to the sky for dark clouds that herald onset of the monsoon. Folklore and nursery rhymes are replete with songs that greet the rains. 'Rain, rain, come again' is a refrain commonly heard.

Yet there are other parts of the world, notably the European continent and the equatorial regions, where rain is an almost constant companion. That kind of close familiarity breeds contempt. 'Rain, rain, go away / Come again another day/ Little Johnny wants to play' is the kind of urgent plea that is commonly heard in those parts of the world. Even those who usually long for the rains can be harassed if they overstay their welcome. Those struck with a cloud-burst start praying for stoppage of the carnage.

Either way, people anxiously want to know when does it rain. Weather bureaus all over the world are entrusted with the responsibility of finding out and then announcing to the world when the rains are likely to arrive. Meteorologists therefore fervently want to know when does it rain. They have, of course, a good idea of the mechanism of rain formation.

Water on earth is not stagnant. It forms a natural cycle. This cycle allows repeated purification of water as also

repeated replenishment of natural reservoirs. It is this cyclic nature of water that sustains life on earth.. Rain is an important part of the water cycle. This is the cycle of evaporation, condensation, and precipitation that distributes water all over the Earth.

The sun is the driving force behind the process of convection which is the main process behind the creation of rain. The sun heats up the sea and this, in turn, heats up the air. The sun cannot directly heat the air. When the water is heated, it turns to water vapour. As the air is warm, it rises up into the atmosphere, taking the water vapour with

it. As it does so, it cools as it gets further away from its heat source, the sea. Eventually, the air and vapour cool to the point where the vapour condenses, making it visible as clouds. The cloud thus contains zillions of tiny droplets of water floating in air.

When a cloud grows, water vapour in the air gradually "condenses" to form lots more tiny little droplets. As the winds move air across the sky, carrying clouds along, fragments of wind known as "eddys" can do strange things to the shapes of clouds. A common game is to study a cloud's shape and guess what it looks like. Also, winds from different directions can collide with each other, which often has great effect upon clouds. It depends on how cold or warm the colliding winds are, and how much water each wind carries.

For rain to happen, the weather conditions inside the clouds, and surrounding them, have to cause the droplets to grow. Some droplets will grow by colliding and combining with each other. Some droplets will grow by acquiring more and more water vapour from the air. Some will do both. But the important thing to remember now is that most of the droplets in the clouds grow at the same time!

But, the droplets do not all grow at the same rate; some grow faster than others. As soon as any get big enough, they start to fall out of the cloud. Water is heavier than air, after all. Depending on the wind conditions, those first raindrops might be blown back up into the cloud, where they can grow some more. Eventually, however, they get too big to stay up in the air, so they fall all the way to the ground. And the slower-growing droplets will fall after them, and so on. This is the essence of the raining process.

Sometimes, rain occurs due to what is called in the scientific parlance, the frontal systems. In the northern hemisphere, the colder air masses come from the north and the warmer air masses from the south. When they meet,

they form a front which is the line between the air masses. The air masses cannot merge as they are of different temperatures. The colder air mass is more dense than the warmer air mass, so carries on pushing forward along the ground. The warmer air mass is lighter than the colder one. So it is forced to rise over the advancing cold air mass. As the air is forced to rise, it cools and water vapour in the air condenses to form clouds. Further forcing of the air, now with clouds, upwards causes precipitation to occur.

Another type of rain falls in the form of thundershowers. The sun provides the heat source, heating up the ground quickly. The ground then heats up the air through convection and the air rises very quickly, carrying any evaporated water with it. As the air rises it cools very rapidly. Large clouds develop directly above the rising air as the air cannot hold as much water. Torrential rain and thunderstorms are caused when the air is cooled to such a degree that water droplets collide with each other in the clouds very quickly. Eventually, the individual droplets become so heavy, that air cannot hold them and they fall as rain.

This is quite common in the tropical regions where it is almost a daily occurrence. The sun heats up the ground quickly during the day, creating thunderstorms in the afternoon and evening. They may extend well into the night-time, before dissipating in the early morning. At other places conditions are more ripe for thundershowers during summer.

Some scientists from the Arizona State University have now come up with some interesting observations about the timing of rain. Their study suggests that rain is most likely to occur along the US Atlantic coast on the weekend and the weather is most likely to be better on a Monday, Tuesday or Wednesday. The most obvious culprit is the "natural" cloud-seeding effect created by the massive drift of East Coast pollution, which also follows a well-defined weekly cycle. If this is true then such variations in rainfall over

different parts of a week should be seen at all other parts of the world where similar industrial pollution takes place.

So when does it rain? It does when the water droplets in clouds get big enough to be heavier than air. Depending on local conditions there is greater likelihood of rain falling in summer, in the evening extending to late at night and on to weekends.

34

WHEN DOES LIGHTNING STRIKE?

Lightning, it is said, never strikes twice at the same place. We do not know what is the genesis of this perception; nor is it clear if it has any scientific validity. Perhaps it is part of the large collection of folklore about this awesome natural phenomenon. A lightning strike is at once frightening and fascinating. Lightning is always a part of thundershowers. Thus, it is a very common phenomenon in the tropical regions. Even in the monsoon fed Indian subcontinent, lightning is associated with early rains.

When a thunderstorm rages, the lightning also occurs. This is because a thunderstorm is classified by lightning. In order for either of the two to be present in the atmosphere, clouds must first form. The clouds form when air near the earth's surface is warmed. Heat always results in expansion. Thus the volume of hot air is greater. Consequently, its density is lowered. Being lighter, hot air would per force rise.

So what does this have to do with the cloud? Well, as the air rises it starts losing its heat and cools down. When things cool, they condense. When condensation occurs, clouds take shape. This, of course, is a brief idea of how clouds form. In reality, however, there is much more involved in cloud formation. But this should suffice for the moment since we are more concerned with lightning. The conditions under which it accompanies, a thundershower is what we should be trying to get at.

The most common thunderstorm cloud is a tall cloud which is precipitating, called a cumulonimbus cloud (*cumulo*

means tall, high altitude; and *nimbus* means precipitation). These clouds form when conditions include upward winds, rather moist air, and cooling temperatures. Within this cloud, there are many electrons giving off their charges. The tendency of charges within a cloud is to have positive charges gather towards the upper portion and negative charges at the bottom of the cloud.

Normally, air acts as an insulator and keeps the two charges apart. So they cannot mix. But at times the difference

between these charges becomes great enough to overcome the air's natural insulation. At such times a lightning flash can come to pass. This charge difference builds up to millions of volts before the stroke of lightning takes place. The lightning bolt is nature's way of trying to maintain equilibrium, a state of balance between all things. This is why the lightning that you see is a discharge of energy in the form of electricity.

A stroke of lightning only takes about half a second to occur. Depending on their path, lightning bolts can be classified into three categories. These are termed as stepped leaders and return strokes. There is also a dart leader. With these three, the path of a lightning bolt can be covered from the place where it leaves the cloud to its connection with Earth.

A stepped leader is a very faint discharge of lightning inside a cloud. These discharges move toward the ground in a series of steps; each step down is about 50 meters long. When the leader steps down to Earth and connects to the ground or a tree, for example, the circuit is complete and the lightning strikes. A return stroke is a lightning stroke that originates from the ground. The stroke travels back to the cloud.

A dart leader happens when electrons are discharged, taking the initial path of the lightning stroke to the ground. This means that lightning can strike the same place more than once. Lightning has favourite sites to strike and is capable of following the same path twice, contrary to what some people believe.

Thunder is a result of lightning. Although many people say "thunder and lightning" it is actually "lightning and thunder". Thunder occurs because a stroke or flash of lightning heats up the air around it so fast that the air expands very rapidly, or explosively. It is said that the air around a lightning bolt heats to five times hotter than the air on the sun's surface!

Since heat makes things expand, like a cake being baked

in a microwave oven, the air expands when lightning heats it. Because the rate of expansion is so fast, the air actually vibrates, causing waves. These waves are the sound waves that we hear as rumbling or thunder.

Thunder travels about one and a half kilometer for every second you count after you see a stroke of lightning. This allows you to figure out how close the lightning struck to where you are. For example: let's say that you see a flash of lightning and then begin to count the number of seconds before you hear the thunder. If you count 5 seconds this means that the lightning struck about 5 km from you.

So when does a lightning strike? It strikes when the electrical charge distribution inside a tall cumulonimbus cloud builds up to such an extent that it can overcome the natural insulation of air.

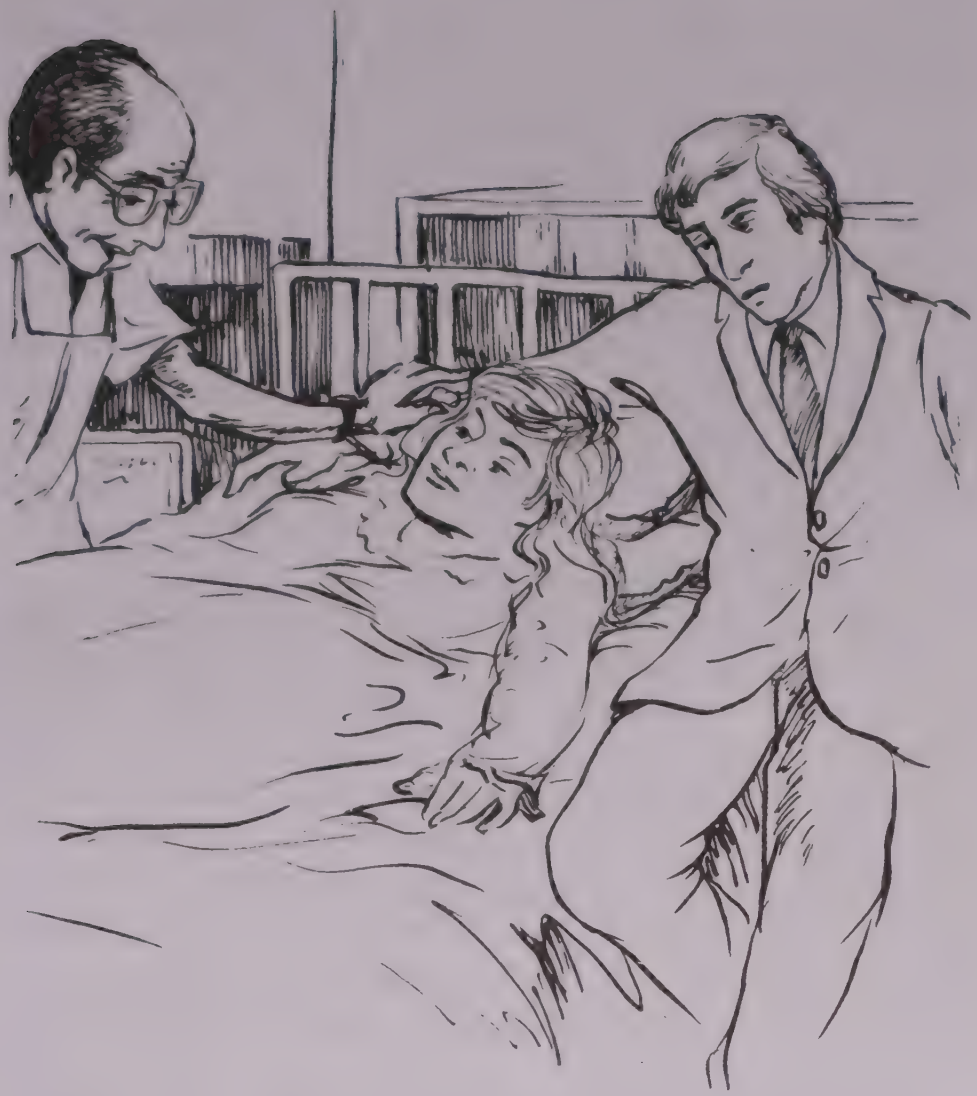
35

WHEN DOES LIFE BEGIN?

Is this a philosophical question? Of course not! It is a very practical question that had the finest legal brains in England tied in knots at one time. It was soon after the birth of Louise Brown, the first test-tube baby in the world. That success of the revolutionary new technology had raised hopes of many a hapless couple not blessed with a child. One such was a very wealthy Australian couple. They approached Dr. Edwards in London who had sired the birth of Louise Brown.

Though the technology bypasses some of the natural processes, it cannot do without a mature female egg to start with. Nature allows maturation in a woman's body of just one egg every month. That egg waits for a while in the expectation of getting fertilised. The womb also makes all the preparations for receiving and accommodating such a guest for the next nine months. If that expectation does not get fulfilled the womb sheds all the paraphernalia it had gathered and the whole cycle begins anew.

Initially the doctors always waited for Nature to hand them the mature egg. Of course, it had to be surgically extracted from the ovary, its usual place of residence. They would then expose it to a multitude of sperms from the would-be father. One of these millions of swimming and floating sperms would enter the egg and fertilise it. It would be allowed to develop further for some time in a glass dish, *in vitro* to use the medical term. Once an embryo—the shapeless mass of cells thus produced—reaches a crucial stage it would be implanted in the woman's body for the



subsequent stages of development that would yield in time a charming baby.

No matter how much man may want to imitate or supercede Nature, the latter has the last word. That is why the success rate of implantation is fairly low even today. In those early days it was woefully inadequate. That meant that the prospective mother had to undergo frequent surgeries for extraction of a mature egg. To spare the woman this trauma scientists had worked out an alternate method. That involved giving the woman a dose of hormones that

would result in maturation of more than one egg at a time. Thus a single surgery would yield quite a few mature eggs. All of them would then be kept in the midst of a swarm of sperms. So, more than one embryo would become available. Even so, only one would be implanted at one time. The rest of the embryos would be kept frozen at a very low temperature for use if and when required.

This refined procedure was adopted in the case of that Australian couple. Unfortunately there was no success the first time around. So they were asked to return for a repeat procedure a week or so later. The couple was rolling in money with a private jet plane of their own. So instead of hanging around in dismal London they decided to head for home, sunny and warm Australia.

Destiny played its cruel hand at this stage. The plane crashed en route killing both of them. The embryos waited in cold arctic conditions. When news of their existence surfaced a woman came forward claiming that she was the legal heir to the estate of that couple. As such she wanted to have those embryos for implantation in her womb. She wanted to fulfill the last desire of her folks and give birth to that baby, the couple had so ardently longed for. Possibly the lady Samaritan had the departed couple's riches on her mind. But her claim had to be settled by the courts according to the law of the land.

The legal experts were flummoxed. They could not quite decide if the embryos qualified to be an estate. Normally an estate in legacy includes movable or immovable property which is inanimate. Living beings like milch cattle or horses do form an estate. But then they are animals. A human being, no matter at what stage of development, was never considered as part of estate. So the judiciary had this question to rule on: Do the embryos qualify to be considered as human beings? When does an amorphous mass of cells become an organism? When does *life* begin?

Since the judiciary could not find anything in laws and codes in vogue that would help them, the ball was thrown

in the legislature's court. The House of Commons constituted a committee with Dame Mary Warnock in chair. The committee consulted a host of experts from diverse fields such as law, religion, social sciences, natural sciences, medicine, philosophy. After a long deliberation it concluded that the amorphous embryo is infused with life on the eighth day after conception. That answer was good enough for the British judiciary to dispose off that particular case. Since the embryos in question were more than eight days old they could not be considered as part of any estate. The claim of that carpet bagging woman was thrown out. Nonetheless, the question continues to be debated even today.

For the moment, however, there is one legally acceptable answer to that conundrum: When does life begin? It begins on the eighth day after conception.

36

WHEN DOES ONE BECOME A MALE?

When a child is born, the first thing that not only the parents but also almost everyone else want to know is whether it is a boy or a girl. That is easily determined in most cases by examining the genitals or external sexual organs. The sex can be known even before the birth of the baby by performing certain tests known as prenatal sex determination tests. These include ultrasonic investigations that are routinely performed these days with a view to ensuring the well being of the foetus. If these tests leave some room for doubt, a sample of the amniotic fluid can be taken out. It is then examined to find out the chromosomal status.

Sometimes, even after birth the external sexual organs do not proclaim the sex of the child in an unambiguous manner. In that case also, blood examination to find out the status of sex chromosomes is resorted to. In later life too whenever external appearance or behaviour gives rise to doubt about the sex of an individual, chromosomal analysis is undertaken to resolve the issue. There have been instances in the history of Olympic games when superlative performances of some female athletes made the authorities wonder if they are indeed what they claim to be. The issue was resolved by undertaking chromosomal analysis.

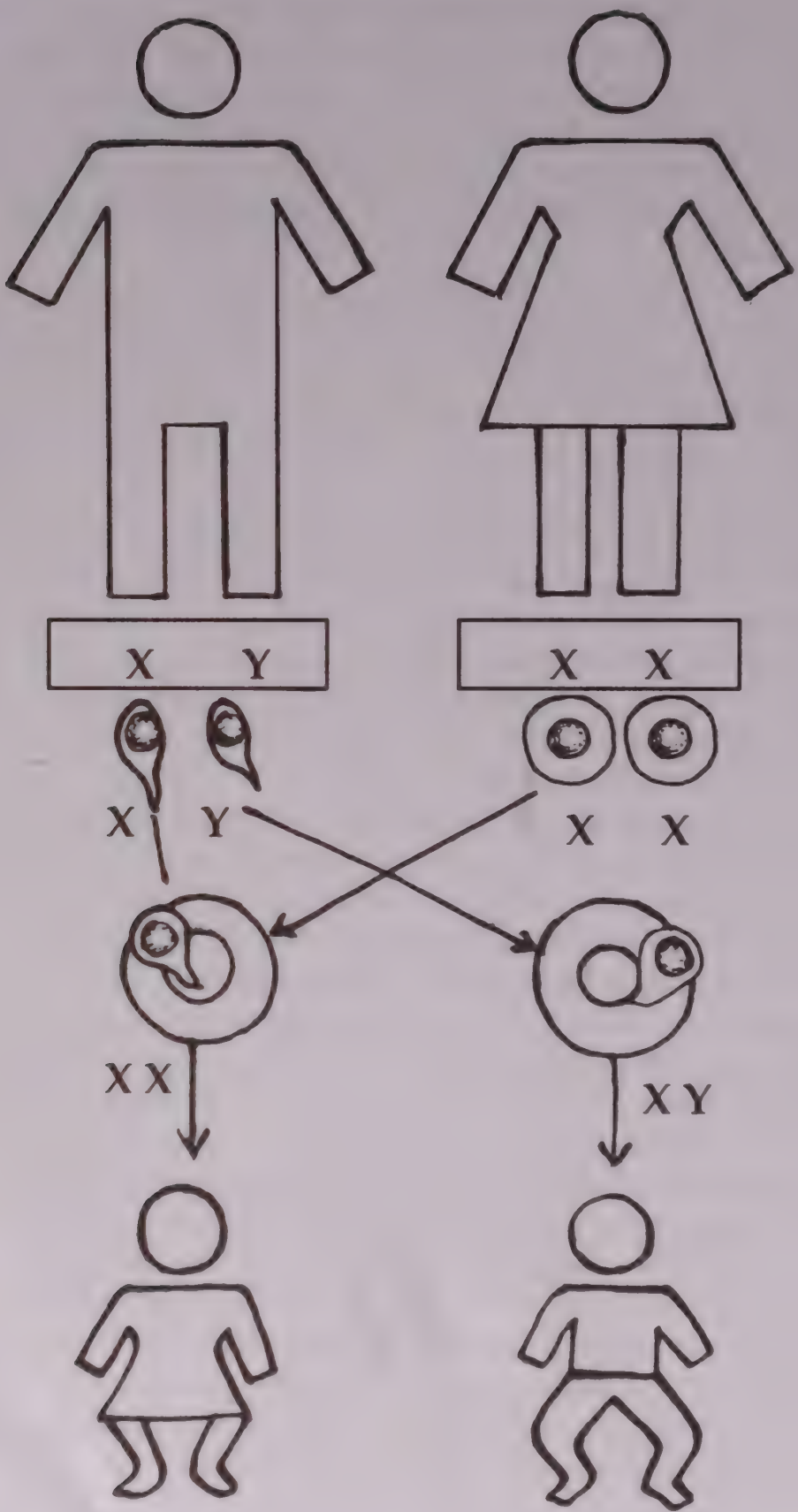
Men and women normally carry twenty-three pairs of chromosomes. Each pair consists of two matching chromosomes, with one exception. The twenty third pair, known as the sex chromosomes, may be made up of either matching constituents or unmatched components. Men

normally have one sex chromosome called X paired with a dramatically smaller one called Y. Women, on the other hand, have two X's. A child, again normally, inherits one chromosome each from the two parents. It always receives a X from its mother. From the father it receives either a X or a Y. If the father bequeaths a Y chromosome, the child will be a boy.

The father carries two different types of sperms, those carrying a X chromosome and those carrying the Y. The mature female egg gets exposed to a very large number of sperms after sexual intercourse between the two partners. These consist of both types. The actual event that brings about fertilisation of the egg involves just one of them breaking through the outer barriers and entering the ovum. There is an equal chance for all the sperms to reach that ultimate target. Yet, in the end only one of them succeeds. Thus, the fate of that fertilised egg is not decided at the moment of intercourse. But does it get sealed at the moment of fertilisation? Is the sex of the resulting child decided at the moment of conception itself?

Prima facie it would appear to be so. If the sperm that wins the race carries a Y chromosome then that should be it. The child should turn out to be a male. So one becomes a male at the time of conception, it would appear. But not so fast. Notwithstanding the nature of the sperm that is responsible for fertilising the egg for a considerable period during embryonic development, male and female embryos are anatomically ambisexual and thus share a number of features in common with regard to early development. Ultimately, male and female structures differentiate into the characteristic male and female features.

Even the development of internal sexual organs like ovaries in females and testes in male shares a common path for a considerable period. At that stage the rudimentary structures are fully capable of taking either route and going on to become a male or a female. So the maleness of an individual is not determined at that stage.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Sometime, even after birth or further development, there is an uncertainty about the sex of an individual. There are people who are XY, for example, but who look for all the world like women. That's because they have a faulty copy of a gene that builds a receptor for testosterone, the male hormone. As a result, their sex organs never get the signal to take on a male form.

Carl Zimmer tells us why. He talks about certain peculiarities of the Y chromosome. It is, he reminds us, "as old as the mammalian lineage. It can be found today in just about every mammal, from human to elephant to bandicoot. But reptiles and birds, the closest living relatives of mammals, don't have a single Y among them. They rely on completely different ways of determining sex. Turtles and alligators, for instance, lay sexless eggs, which become either male or female depending on the temperature at which they incubate. Birds, like mammals, use sex-determining chromosomes, but theirs aren't related to ours. Biologists call them W and Z. While our two X's make a woman, two Z's make a male bird; a W and a Z make a female. Without any version of the Y to be found other than in mammals, there's only one conclusion to draw: Our ancestors must have evolved after they branched off from the ancestors of birds and reptiles, a split that paleontologists think happened about 310 million years ago."

The failure of the fertilised egg to adopt a distinct sexual characteristic during those early days of development is due to this eccentric nature of the Y chromosome. Further, during evolution it has arisen from the X chromosome itself. This became clear when the project to read the entire human genome got under way. The Y chromosome was seen to be a genomic runt, containing only 60,000 nucleotides, the organic compounds that make up DNA. With 165,000 nucleotides, the X chromosome is nearly three times as long. And when you look at the actual number of working genes on the Y, the difference is even more striking. The Y has only 50, while the X has 1,500. Yet X and Y are apparently

cousins, descended from an ancestral pair of matching chromosomes. Scientists have discovered that a number of the Y genes have strikingly similar counterparts on the X chromosome. The simplest explanation for this is that a matching pair of chromosomes in some primordial mammal diverged to become the X and the Y.

Thus only a few genes on the Y chromosome appear to be unique. They should, therefore, be responsible for endowing an individual with maleness. A crucial one among these appears to be the SRY gene. Of course, making a male is a complex process involving many more genes. But there would be one that probably sets the ball rolling. In 1990 a team led by Peter Goodfellow, then working at the Imperial Cancer Research Fund, discovered such a trigger. They called it SRY gene.

If a Y-bearing sperm carries a defective copy of SRY, and it can take as little as one incorrect nucleotide to disable the gene, a child will grow into a female despite its Y chromosome. The reverse is true, too. In a neat experiment, a team headed by Robin Lovell-Badge at the National Institute for Medical Research in London plucked an SRY gene from a male mouse and added it to the paired X chromosomes of a fertilised mouse egg. The mouse embryo grew into a male.

So, now one can answer the question when does one become a male with a little more confidence. Though one cannot fix a specific time for it to happen, one becomes a male when a normal SRY gene gets activated.

37

WHEN DOES ONE BECOME BIASED?

Notwithstanding all the efforts to inculcate scientific temper, people have a tendency to continue to hold dearly to some pet points of view. They refuse to have any objective assessment of the issues and jump to conclusions on the basis of emotional responses. This is what gives rise to a mindset where foreigners are always being looked at with great degree of suspicion. The Indian caste system still holds sway due to such subjective evaluation. Not only parents refuse to give consent to their children marrying outside the fold or *biradari* but even go to the ridiculous extreme of refusing transfusion of blood from a person not belonging to their caste. Elders condemning everything that the younger generation does also are victims of such biased opinions. The much talked about generation gap is a result of these jaundiced views.

Embracing such chauvinism becomes more common as one gets on in years. As one starts greying, one finds it difficult to accept newer concepts. On the contrary, the elders find it easy, and more reassuring, to hold on to tried and trusted attitudes. It is much like the unwillingness to throw out an old shoe. However tattered, it appears to be more comfortable, almost like a security blanket. In relation to the younger breed in the same family, the old folks are averse to changing their set course and welcoming newer views. Even those, who had in their younger days vouched for uncompromising objectivity, tend to give it a miss as they advance into more ripe years. The general belief is that the older one gets, the more prone one is to prejudicial

outlook. But hold on! Is this really true? Or is it also another example of unsubstantiated bias against the senior generation?

Neurologist von Hippell from Ohio State University avers that it is not a partisan judgment. As one gets older, one indeed starts abandoning rationality and holding on to notions that may not find substantiation. He came to this

conclusion after conducting some elegant experiments.

For this purpose he got hold of two groups of volunteers. One of these two groups consisted of 36 young people aged between 18 and 35. The other was made up of 35 senior citizens all above 65 years old. He then gave some members of both groups a paragraph to read. It contained a fairly detailed biodata of one 'Jamal' who was a star member of the university football team. The remaining members of both groups were handed over a similar paragraph describing the life history of one 'John' who was also a university student but had stayed away from the playing fields. Instead, he had excelled in the academic arena. The names of the two students were deliberately chosen. 'Jamal' gave an impression that he belonged to the black African-American community. 'John' was a stereotypical name for a white American. No attempt was made to explain their true racial identities.

Having read the paragraphs everyone was now given another document. This listed responses of both John and Jamal to a set of questions inviting their views on a range of subjects. There was not much difference in the responses of the two students. Their language and style of expression did differ but the underlying concepts and principles were fairly similar.

All the volunteers were now asked to evaluate personalities of the two students. To aid further statistical analysis the members of each group were asked to grade both John and Jamal on a scale of 10. A grade of 1 would suggest poor rating. On the other hand, a grade of 10 would be indicative of very high esteem. The volunteers were admonished to make their assessment solely on the basis of the second document that delineated views of the two students and not let information of their biodata influence their judgment.

Yet most members of the senior group found Jamal to be intellectually inferior whereas John was considered very intelligent. Most of them were of the opinion that African-

American innately have poor intelligence. The younger group, in contrast, did not discriminate between the two students in such a forthright fashion. They did not seem to consider the black population to be lacking in intellectual capacity.

The seniors thus were clearly seen to harbour prejudicial views about different racial groups. The impression that as one ages one tends to become more prejudicial was supported by experimental evidence.

Von Hippel did not stop there. He went on to determine whether this was merely a cultural attribute or it had any biological origin. He found that certain degenerative changes in the structure and function of our brain caused by the ageing process are responsible for this intolerance of fresh views on the part of the older generation. They simply find it unable to accept a fresh breath of air in spite of their innate willingness to try out newer concepts.

Our brain receives inputs from our senses all the time we are awake. The five senses gather information about the surroundings and transmit it to the brain. So a good many bits of information keep bombarding the brain at the same time. If all of them are to be registered, analysed and then stored in appropriate compartments for possible future use it would create an untenable situation. So the brain has developed a way of suppressing, at times totally ignoring, less important stimuli.

For example, suppose you are engaged in doing some serious reading. While you are doing so the rattle of the traffic outside your window is also trying to catch your attention thanks to the ever vigilant audio-sensory mechanism. The aroma of food being cooked in the kitchen is also trying to entice you through the olfactory mechanism. There could be other similar inputs being received by the brain even as your eyes are sending in impulses about the words in front of them. If all of them are given the same importance you would be unable to concentrate on your reading and make sense of the difficult paragraph that you

are working your way through. So the brain suppresses all the other electrochemical impulses and works on the visual input alone. You are thus able to give your unwavering attention to the book in hand despite all the other distractions.

However, as one ages this ability is impaired. The brain is not able to make such important discriminations between different inputs easily. That is why whenever one comes across a new thought it has to wrestle with the older thoughts deeply ingrained in memory on an equal basis. While one is young one is able to suppress the onslaught of the ingrained ideas, at least temporarily, so as to allow objective assessment of the fresh concepts. That cannot be so easily accomplished as one ages. The more advanced one is in years the less one is able to suppress unwanted intrusions. This inability to give newer thoughts a try is the root cause of prejudices getting built up.

But when does this transition in one's brain take place? Well, there is no specific date. It appears to be a gradual process. Then again it is also individualistic. Some may be able to stem the inevitable decline in brain's ability for a long time. Others may lose it relatively early. So, when does one become biased? One does so as the degenerative changes in the brain cross a certain threshold.

38

WHEN DOES ONE GET INTOXICATED?

"Never! I never get tipsy! I can hold my drink very well." Almost everyone will be prepared to state this on oath. And yet everyone knows that if one crosses that limit—one would 'tipple' over and get tipsy. The one for the road may become the one that takes you on the road to 'drunkenland'. What was happy hour till then turns into miserable minute. But when exactly does this crossing over take place? Which sip is the proverbial last straw that breaks the camel's back.

To understand that one has to first understand the structure of a hard drink and what it does to one's body and mind. Ethyl alcohol, or ethanol, is a psychoactive drug found in beer, wine, and hard liquor. It is produced by the fermentation of yeast, sugars, and starches.

Alcohol acts as a sedative on the central nervous system. It is rapidly absorbed from the stomach and small intestine, passes into the bloodstream, and is then widely distributed throughout the body. The effects of alcohol on the body are directly related to the amount consumed. In small amounts, alcohol can have a relaxing effect. Adverse effects of alcohol can include impaired judgment, reduced reaction time, slurred speech, and unsteady gait. It also causes impaired vision, coordination, and concentration.

When consumed rapidly and in large amounts, alcohol can also result in coma and death. In addition, alcohol can interact with a number of prescription and non-prescription medications in ways that can intensify the effect of alcohol, of the medications themselves, or both. But the part of the brain it affects the most is the one responsible for behaviour

and emotion. Your sense of judgment is weakened, and your inhibitions disappear. All of a sudden, speaking your mind doesn't seem so bad. You feel braver since your socially conditioned safety stops, or filters, are circumvented. This is why drunken people sometimes think they're okay to drive.

When you drink on an empty stomach, there's no food to slow down the rate of absorption of the alcohol. Alcohol

gets absorbed through the lining of the stomach and the intestines and into the blood, where it is whisked throughout the body and to the brain. Blood-alcohol content begins to creep up, and the subtle first effects of intoxication begin to buzz through the nervous system. You get intoxicated more rapidly. On the other hand, drinking alcohol on a full stomach allows you to go through a gradual ascent into tipsiness.

Though it mostly acts as a sedative it diminishes the quality of sleep. Individuals with sleep apnea often experience longer and more severe apneic episodes and hypoxia, or oxygen deprivation, after drinking alcohol. In other individuals, though, alcohol may act as a stimulant. Indeed, its association with violent and self-abusive behaviour is well documented. At intoxicating levels, alcohol is a vasodilator. It causes blood vessels to relax and widen. However, at even higher levels, it becomes a vasoconstrictor, shrinking the vessels and increasing blood pressure, exacerbating such conditions as migraine headaches and frostbite.

Just as our brains begin to feel the frothy effects, the booze bomb disposal squad, a host of enzymes called alcohol dehydrogenase, specifically engineered to break down alcohol, gets to work to help metabolise the alcohol into components that, ultimately, can be either used or expelled from the body. Alcohol dehydrogenase comes in limited supplies. They can generally metabolise about one alcoholic drink an hour, that is one 350 ml bottle of beer, about 50 ml of hard liquor, or about 150 ml of wine. These, of course, are average levels. Exact levels will differ from person to person, lifestyle to lifestyle. That's why some people tend to get more intoxicated than others do. We can only break down so much alcohol over a period of time.

The body starts breaking down alcohol as soon as you take your first sip in order to safely excrete it. To properly dispose of it, your liver needs water to dilute the toxins, so it pulls water reserves from other parts of the body. But

since alcohol is a diuretic, it stimulates urination. Thus, water leaves your body at a higher rate. Consequently, your liver must obtain water from other organs, including your brain, which essentially leaves you high and dry.

Prolonged alcohol use does increase one's tolerance to the stuff. The body becomes more efficient at metabolising the alcohol. The process is up to 72 per cent faster in alcoholics. So it takes more booze to achieve the same drunken state. But beyond that, your organs simply become less sensitive to alcohol, so you don't feel it as much. If that happens then that is a danger sign. Because this state is a precursor to permanent tissue damage.

Excessive drinking, including binge and heavy drinking, has numerous long-term as well as short-term health effects. Chronic health consequences of excessive drinking can include liver cirrhosis or irreversible damage to liver cells. It may also induce pancreatitis, that is, inflammation of the pancreas; various cancers, including cancer of the liver, mouth, throat, larynx and oesophagus. It can also lead to high blood pressure; and psychological disorders. Acute health consequences of excessive drinking can include motor vehicle injuries, falls and domestic violence.

It is, therefore, important to know when does one get drunk or intoxicated. He does so when one takes an overdose of alcohol or imbibes it at a very fast rate or consumes it on an empty stomach. However, the number of drinks that an individual needs to consume to get drunk varies from person to person, based on a number of factors, including age, gender, physical condition, and the amount of food eaten before drinking, the use of drugs or medicines, and many other factors. However, binge drinking, for a man—consuming 5 or more drinks per occasion; and for a woman—consuming 4 or more drinks per occasion, typically results in intoxication.

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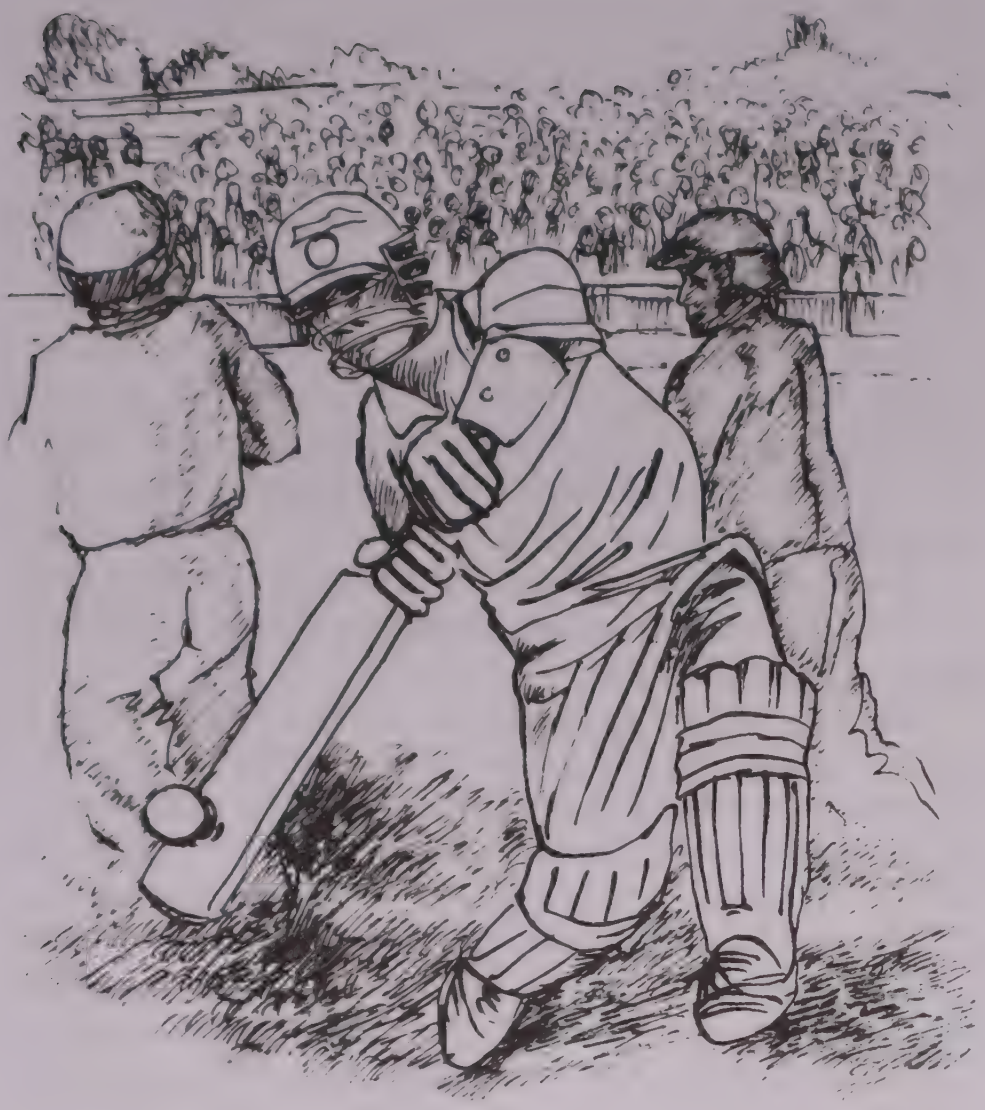
WHEN DOES SACHIN SEE THE BALL?

Smarting at the cavalier treatment meted out to the previous delivery that saw the ball racing to the mid-wicket boundary, Shoaib Akhtar gives his full shoulder and hurls the red cherry menacingly at the batsman. Only to see Virender Sehwag contemptuously dispatching it to the cover fence. That was Multan in 2004.

Veeru is not the only one to indulge in such pyrotechnics. There is the master blaster, Sachin Tendulkar, on whom Veeru confesses to have modelled himself. There are yet others like Adam Gilchrist, Sanat Jayasurya and of course the Ranchi Rambo, Mahendra Singh Dhoni. They can make the most fiery bowler look no more than an average trundler. Their shots may not find a place in any copy book. They may defy all rules and logic. Yet the unorthodox shots are executed with such finesse and nonchalance that the spectator, the bowler and the fielders are often left speechless. So much so, that bowlers of repute have no clue whatsoever as to what type of ball would at least keep these valiant wielders of willow a little bit subdued.

How are these phenomenal players able to achieve such prodigious feats? Sports critics will do a Dhoni in giving you a swift explanation. "Quickness of the eye", they will say, enables these legendary batsmen to put the bowling to the sword. These talented players, it is contended, are able to spot the ball early, judge its speed, length, swing, and turn quickly, so that they have ample time to place themselves in the right position to send the ball anywhere they desire and with a timing that makes the sound of the



willow hitting the leather music to everyone's ears.

Satisfactory as that explanation may be, many, mere mortals like us, and perhaps the suffering bowlers as well, would like to know when exactly do they see the incoming ball. Is the time when they see the red sphere approaching them any different from that when others are able to see it? Would we ever know? Well, good help is on the way. Scientists have now come to our rescue and have tried to find out when the master blasters see the ball.

Peter McLeod of Oxford University, therefore acquired a bowling machine. This could pitch the ball at various speeds and differing angles. To add to the complexity of the situation, McLeod insisted on a matting wicket. And then placed odds and ends under the mat for good measure. That made the bounce of the ball as unpredictable as the English weather.

Armed with high speed camera McLeod then focused on the angle of the bat. He computed the time it took the batsman to react to the deflection of the ball as reflected in the change of the angle of the bat. To arrive at this he identified the movie frame which caught the instant at which the ball bounced off the pitch. The number of frames that spanned that instant and the one at which the angle of the bat was commensurately altered, gave a measure of the batsman's response time.

The results came as a surprise: The agile players took as much as one-fifth of a second to register their reaction. This was not significantly different from the time period ordinary people need to respond to a visual stimulus. Apparently, the professionals are no quicker in their reflexes than novices. How is it then that they are able to cut any bowler down to size and massacre his bowling? That is because, McLeod says, with constant and rigorous practice the professionals are able to coordinate their movements more effectively within the same time interval as is available to the amateur.

Independent researches from scientists across the Atlantic substantiate McLeod's inference. Matthew Shank and Kathleen Haywood have examined baseball players of distinction. Baseball is the Yankee version of cricket. Since the ball is 'thrown' at the batter rather than 'bowled' and the bat is more of a truncheon lacking the breadth of the cricket blade, quick reflexes are all the more crucial to hit a home run.

Shank and Heywood also adopted a different strategy to find an answer to the nagging question: 'When do they

see the ball?' They recorded on videotape a top ranking pitcher in full action throwing 20 different types of balls. They then got hold of a group of expert players and another consisting of weekend amateurs. The video film of the pitcher was then shown to both the groups, one member at a time. Each one was instructed to concentrate on the bowling., as if they were facing the pitcher in a real-life situation. The movements of their eyes in turn were videotaped.

All of them, expert and novice alike, took the same amount of time, some 150 milliseconds, to make the first eye movement after the ball was released by the pitcher. But the professionals were able to precisely focus on the 'release point' of the pitcher by anticipating it accurately. From that point on, their eyes never left the ball until the bat made contact with it. Secondly, practice presumably helped them to identify the type of ball the pitcher was going to hurl at them, albeit within the same interval, to plan their attack or defence. It also helped them to calculate the precise position of the ball at any point in time, so that the bat would be brought at that very location precisely at that instant. The timing thus achieved was very sweet.

What sets the men apart from the boys, thus, is not so much the time of response, but more efficient management of that time. *When* Sachin sees the ball is not so important obviously as *where* he looks. So apparently we are back to the *Mahabharata* and Arjuna who was such a crack archer because he had eyes only for the eye of the fish and not for the multihued scales which would otherwise waylay one's attention.

40

WHEN DOES WATER BOIL?

That is easy, you might say. After all, every school student knows this. Of course, water boils at 100 degrees celcius. Or 212 degrees Fahrenheit if you prefer the American way of saying it. Well, you may be correct. But is it always so? Go ask someone staying at Leh in Ladakh, or Simla, or Kodaikanal for that matter. He will not agree with your statement. If you doubt him try cooking your *dal* there or boil an egg. It would seem that it takes ages for that simple task that you are able to accomplish in your place in a jiffy. That is because if you were to dip in a thermometer and measure the temperature of the boiling water you would find that it is less than 100 degrees centigrade. It is not the fault of the thermometer. The very same instrument would show the temperature of boiling water at home as 100 degrees centigrade all right.

The reason for this apparently strange behaviour is to be found in the altitude at which Leh, Simla and Kodaikanal are situated. They are way above the mean sea level and hence the atmosphere there is rare. That is why when one reaches Leh one is advised to take bed rest for a couple of days till one's body gets acclimatised to the atmosphere there.

Lest one feels that this is all hot air listen to the astronomers. They will tell you that on Mars water boils at a cool 10 degrees celcius. That is when it has hardly melted. So as they say in advertisements announcing several discounts, 'conditions apply'. Exactly when would water boil would depend on the atmospheric conditions at the particular place.

The atmosphere surrounding us exerts a certain amount of pressure. This pressure at sea level is about 1 kg per square cm. It is the density of the atmosphere, or air that causes the pressure. As the altitude increases, the density of the air becomes lower, and this thinner or less dense air then exerts *less* pressure. So, the higher the altitude, the less dense the air, and pressure decreases, until in space—no air, no density, no pressure.

Now, to boil water requires certain amount of energy. This energy is in the form of heat. As the water molecules are heated, the energy of the water molecules is increased. So they will vibrate or become more agitated, until finally

the water molecules will break loose from the surrounding liquid water and rise up as steam. The water will also move quite violently due to the expanding dissolved gases that are contained in the water.

The atmospheric pressure at sea level compresses the water molecules together into a liquid. So there is a certain amount of bonding energy between each water molecule. Addition of energy in the molecules helps them overcome this bonding energy and free themselves. Thus they enter the gaseous phase. With increasing altitude, the external pressure on the water is decreased; therefore it will take less energy to break the water molecules free from their bonded state. If it takes less energy, then it will take less heat. If less heat is required, then less temperature is required, then the water will boil at a lower temperature

Because the Martian air has a very low pressure, fresh liquid water on Mars would boil at a frigid 10^0 C. On the other hand, in a pressure cooker the pressure is raised and is higher than that outside. Hence a much higher temperature has to be attained before water inside a pressure cooker would get to boil. That is the reason that even those foods, say, like meat or certain *dals* that are hard to cook can be easily cooked in a pressure cooker.

Thus the exact stage at which water boils is dependent on the atmospheric pressure. When you heat the water, some of it starts to turn into steam and escape into the air. As the water gets hotter, more steam appears. The air around the saucepan, however, is pressing down on the water's surface. This air pressure resists the upward pressure created by the escaping steam. Before the water can boil, the pressure of the steam must get high enough to equal the air pressure on the water's surface. When that happens the water won't get any hotter. Adding more heat just turns the rest of the water into steam. Scientists state this fact by saying that water boils when the vapour pressure is equal to the atmospheric pressure.

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WHEN IS A BLACK HOLE LIKE A DRIPPING TAP?

A black hole is at once a fascinating and frightening entity. It is something that scientists predict exists. Yet because of its peculiar characteristics we cannot see it even with the help of the most powerful telescope. How can one be sure then that it is really present? The question would naturally pop in anyone's mind. The influence that such a mysterious body has on its environment and the resulting queer behaviour of its surroundings betrays its existence. These properties of the black holes have even enabled scientists to produce their photographs.

A black hole is a region of space that has so much mass concentrated in it that there is no way for a nearby object to escape its gravitational pull. It may perhaps have been easy for us to swallow this statement prior to 1957. But in that year Russia sent a tiny *Sputnik* into space and all our concepts about gravity underwent a revolutionary paradigm shift. For the first time we saw that an object could escape the gravitational pull of the earth and go into space. A new term called "escape velocity" came to occupy a place in the dictionary. One even calculated its magnitude and showed than an object had to attain a velocity of 11.2 km per second to escape the gravitational attraction of the earth.

We also came to know that the exact magnitude of this escape velocity would depend on the mass of the pulling object. Since the moon has a lower gravity, the escape velocity there would be as low as 2.4 km per second.

Now let us go to the other extreme and imagine a body

with such mass and hence such strong gravitational pull that the escape velocity would be greater than that of light. But Einstein had decreed that speed of light is the mother of all speed limits. So nothing can move faster than that.

Obviously then nothing can achieve that escape velocity. Consequently, anything that is trapped in that gigantically massive object can never dream of escaping its gravitational pull. Not even light. It would be dragged back even as it ventures to get out. Since even light cannot get out, the body came to be called a "black hole".

This was the theoretical culmination of Einstein's General Theory of Relativity. But was it merely an intellectual curiosity? No, it wasn't!—pronounced Oppenheimer and others. They predicted that black holes indeed do exist in the universe. Our own Subramanyam Chandrasekhar, the Nobel laureate, went one step further. He proved that the cradle of black holes can be found in the cemeteries of stars. Stars too have a finite lifetime. They are born, live an illuminating life for some time but eventually die. When they do in a spectacular fashion, known as the supernova, they get converted, if they are massive enough, into a black hole. He even calculated the minimum mass that a star would have to achieve, in order to give birth to a black hole on its own death.

According to Einstein's General Theory of Relativity, space and time are not separate entities but are inexorably linked together into one unitary fabric. Whenever a massive object is placed on this fabric it creates a dimple and the fabric acquires some curvature. Thus gravity is a manifestation of this curvature of space–time. Massive objects distort space and time, so that the usual rules of geometry don't apply anymore. Near a black hole, this distortion of space is extremely severe and causes black holes to have some very strange properties. In particular, a black hole has something called an 'event horizon'. This is a spherical surface that marks the boundary of the black hole. You can pass in through the horizon, but you can't get back out. In fact, once you've crossed the horizon, you're doomed to move inexorably closer and closer to the 'singularity' at the centre of the black hole.

The properties of black holes thus defy imagination

and hence have held the attention of scientists the world over. The pitch was further queered by Einstein himself, albeit indirectly. He had proclaimed that the universe is not three but four dimensional, time being the fourth dimension. At the same time he had also promoted the concept that there is but a single fundamental force that holds the universe together and is responsible for running it smoothly. He spent almost twenty years of his later life trying to come up with an equation that would describe such a universal premier force. However, success eluded him.

But the idea was infectious. A number of brilliant scientists have been bitten by the bug. They conceived several ingenious theories in order to reach the goal that Einstein failed to arrive at. One such is the "String Theory". One of the tenets underpinning this theory is that the universe exists in several miniscule dimensions besides the four, so elegantly demonstrated by Einstein. As it is the extreme, densities inside black holes make them incredibly difficult to model even in the three spatial dimensions familiar to us. The addition of these extra dimensions makes it even more complex. This is because Einstein's equations must be solved in every single dimension. Even with powerful computers, it takes a very long time. Moreover, one doesn't really have an intuition as to what might happen in other situations. So each time one tries a different geometry, one has to start from first principles all over again.

In string theory, black holes can take on a variety of shapes, including long strings. Previous research had shown that these "black strings" are unstable and quickly break apart if their radius is about the same size as the extra spatial dimensions. That means that large black strings—which we detect as black holes with the mass of the Sun or more—are large enough to remain stable for billions of years. But tiny black strings—perhaps just a few tens of metres across—would be unstable.

Victor Cordoso and Oscar Dias of the Perimeter Institute

for Theoretical Physics in Canada have shown that a similar instability occurs due to the surface tension in liquid "membranes". Therefore, these black strings quickly disintegrate into spherical black holes. This is similar to what happens when water is dripping from a tap. It also breaks into small droplets. So everyone struggling to understand how black holes behave in the extra dimensions posited by string theory should turn off their computers and turn on their kitchen taps instead. For, those mysterious objects act just like narrow streams of water that begin to separate into drops. But when does this happen? When is a black hole like a dripping tap? It behaves like a leaky kitchen faucet when it is very tiny, almost of the same size as that of the dimension in which it exists.

42

WHEN IS PAIN FIRST FELT?

Let it be made clear that this is not a philosophical question. Otherwise some would start by asking a counter question, is pain always felt. They may also like to draw our attention to the observation that Indian Yogis never feel pain. Then again, there are certain masochistic individuals to whom pain is pleasure itself. But the intention of raising this question is not to get involved in such semantic or pedagogical arguments.

The question is a real one. It asks one to specify the time in one's life when the sensation of pain starts getting registered for the first time. The genesis of the question lies in the anti-abortion movement in the US. Since abortion, or medical termination of pregnancy to give it its rightful medico-legal name, was legitimised a number of religious, women's and human rights organisations in that country have been opposing the practice. Their objections, as indeed objectives, were different. But they were united in their hostility to the procedure of aborting a foetus, with or without consent of the concerned parties.

One of the objections raised by the human rights groups related to alleviation of pain during the procedure. They argued that while the prospective mother is spared the trauma of feeling pain during the surgical procedure, the unborn baby is not. While the mother is administered anaesthesia to make her unaware of the surgical intervention, no such courtesy is extended to the foetus. It has to thus go through the entire procedure enduring pain without even a chance of saying 'ouch'!

The medical and legal fraternities thus were confronted with the question: Does the foetus feel pain? If so, when exactly does this sensation arise in the developing embryo? Is it from the moment the father's sperm fertilises mother's ovum to from the zygote? Is it at some stage thereafter?

Some argued that every living being feels pain. Since the fertilised egg is also infused with life it would also feel pain from the moment it comes into being. That argument, logical though it seems on the face of it, flies in the face of facts. For one, not all living entities feel pain in the same sense as we humans do. Plants are also living. There is no credible scientific evidence that they feel pain. No doubt they are capable of receiving external stimulus and responding to them. That is why they flourish in response to supply of water and food, and fertilisers. They do respond to seasonal changes in ambient conditions. That is why they start flowering at the onset of spring and shed their foliage as autumn sets in. But there is no evidence that they 'feel pain' when an axe falls on them. The micro-organisms, like bacteria, do not register any detectable response to attack by 'magic bullets'. So not every living entity is capable of registering the sensation of pain.

Secondly, life does not begin as soon as conception takes place. For infusion of life, the fledgling embryo has to wait for at least eight days. That has been the verdict of the parliamentary committee constituted by the House of Commons in Britain, specifically for the purpose of deciding when an embryo qualifies for being considered a living entity.

Even so, after eight days it is a live entity. Abortion is usually carried out much later. So the argument of the opponents of abortion seemed to have some logic. Neurologists, nonetheless, argued that for pain, or any sensation for that matter, to register, a neural network would have to get established. Unless there are nerves that can convert the stimulus sensed by the external sense organs into an electrochemical pulse the sensation cannot be

registered. These nerves attached to the sense organs carry this impulse to the central nervous system. Thus, pain cannot be felt without the peripheral nervous system being in place.

The first 8 weeks after implantation are termed the embryonic period. It is during this time that the organs, systems and tissues of the future being are induced, differentiated, and put into place. The remaining 30-40 weeks of gestation are devoted to growth, development and refinement of these organs, systems and tissues. At about 14 days, the embryo is about 2 millimetres long. By the 17th–20th day of gestation, the primitive embryo develops what is known as the 'neural plate', which is a sheet of cells that will ultimately develop into the nervous system of the individual. By the 23rd day, or the third week of development of the new entity, the neural groove, which is the embryonic brain structure, is visible. Two days later, the edges of this groove, which have continued to 'curl up' until now, start to join together to form the neural tube, which forms the basis of the entire nervous system. The neural tube is, of course, the precursor of the spinal canal. Brain functions are expressed through activity of neural circuits.

This seems to take place at around 13 weeks of pregnancy. "Aha!" said the anti-abortion lobby. "You said it. At least then the foetus would start feeling pain". So a pregnancy that has advanced beyond 13 weeks should not be terminated, it would be inhuman to do so.

But the neurologists were not convinced. Mere recording of the external stimulus cannot be equated with what we term as sensation, they contended. Whenever cells of the external sense organ detect a perceptible change in the environment, they record it. The nerve cells convert that impulse into an electrochemical pulse that then travels all the way to the central nervous system in the brain. The concerned centre in the brain receives that pulse and analyses it with a view to deciphering it. Only when that

happens we perceive it for what it is.

For example, whenever light reflected by an object falls on the retina, the rod and cone cells making up that organ are stimulated by the light ray. That stimulus gets converted into an electrochemical pulse by the optic nerve attached to it. The pulse travels to the brain where it is analysed, compared with the stored information in memory. Only then we 'see' and 'recognise' that object. This is true of all the sensory organs.

Pain in an adult, child, newborn or late-term foetus originates as an electrical signal in some of the body's pain receptors. This signal is sent via nerve pathways to the spinal column, then to the thalamus—an egg-shaped structure within the brain. Finally the signal is transferred to the cerebral cortex where it is sensed as pain. In a foetus, the pain receptors develop around 7 weeks after conception; the spino-thalamic system at about 13 weeks. However, the connections to the cortex are established only after about 26 weeks into pregnancy.

In the year 2000, The House of Lords in Britain conducted an inquiry into "fetal sentience". One part of the study dealt with the ability of a foetus to feel pain. Conventional wisdom among researchers is that the brain's cortex is the only location where pain can be felt. They concluded that:

(a) After 23 weeks of growth, higher areas of the brain are active and starting to form connections with nerves that will convey pain signals to the cortex;

(b) By 24 weeks after conception the brain is sufficiently developed to process signals received via the thalamus in the cortex; and

(c) While the capacity for an experience of pain comparable to that in a newborn baby is certainly present by 24 weeks after conception, there are conflicting views about the sensations experienced in the earlier stages of development.

The current scientific understanding is that 6 weeks after conception the elements of the nervous system start to function. Most scientists currently agree that this marks the earliest possible point at which sensation might occur.

So, the jury is still out on that vexing problem. When does one start feeling pain? The answer to that question will probably depend on how you define 'feeling' as well as 'pain'.

43

WHEN WAS AMERICA DISCOVERED?

Of course, it was discovered in 1492, wasn't it? And Christopher Columbus did it. That would be the most popular answer. In a quiz contest, the quiz master would award full marks and quickly turn to the next group and the next question. That would have been alright a decade earlier. Today, however, it is another story. The quiz master would be told not to be so fast. A very lively debate is ensuing among archeologists on account of a number of claims to the contrary, each one of them supported by what is contended to be incontrovertible evidence.

The strongest contender is what is known as the Vinland map. It shows Europe, North Africa, Greenland and the north-east of America. It bears the legend: "Island of Vinland, discovered by Bjarni and Leif in company". If genuine, it is the oldest map of America, and commemorates Leif Ericsson's journey to what are now Canada's Labrador and Newfoundland provinces in the AD tenth century.

The story of his discovery of this new land is very fascinating and involves the discovery of two other territories later colonised by the Scandinavians. It all started with Eirik the Red. Eirik the Red was born in Norway but in his youth he, with his father, went to Iceland. Here Eirik became a freeholder and married a native girl, the daughter of an Icelandic chieftain. To them were born three sons, one of whom was Leif the Lucky, discoverer of America.

Not only did Eirik the Red take his red hair and beard to Iceland but also his fiery and combative disposition. This, in due time, involved him in disputes and feuds, and

finally led to his banishment from Iceland for a period of three years. The adventurous Eirik resolved to use this time in an attempt to discover a new land of which he had heard. He fitted a ship and sailed until he discovered habitable land where he established his residence and proceeded to explore this new country. He named the new land "Greenland" in the hope that such an alluring name would entice settlers. His glowing reports appealed to the

adventurous Icelanders with the result that, the following spring, Eirik returned to Greenland with 25 vessels and established an Icelandic colony there under the same laws and customs which prevailed in Iceland.

In the spring of 1000, Leif who had returned to his native Norway, set sail for Greenland by way of the short route directly across the Atlantic. He was driven out of his course and came to a land which he had not seen before, a land of trees and grapevines which he accordingly named Vinland (Wineland). He returned to Greenland and Iceland where the stories of his new discovery spread rapidly and aroused much interest and enthusiasm among the people. Many sailed for the new world. Some promptly reached their goal while others were unsuccessful. Those who returned told about different places in the new world which they designated by some names such as Helluland, Markland, and Vinland. Those names and accounts are fitting descriptions of certain regions, along the east coast of North America.

The Vinland map attributed to Lief Ericsson came to light in 1957, when Yale University paid US $1 million for it, and published it in a blaze of publicity. At the time the idea that the Vikings colonised America before Columbus was new and controversial; archaeological findings have since confirmed it.

Some have always questioned the map's authenticity. Doubters felt vindicated when, in 1974, crystals taken from the map were found to contain anatase, a titanium compound used in a white pigment that was invented in 1923.

In 1985 believers got a boost. X-ray analysis showed that the map, like other medieval documents, contains only traces of titanium. These could have been picked up from dust or during handling.

Nonetheless, the debate continues even today as analysis of the paper as well as the ink used to draw the map carried out with even more sophisticated scientific techniques like radiocarbon dating and laser Raman spectroscopy has

thrown up conflicting results. Some showed that the parchment paper on which the map is traced belongs to the middle ages but the ink is from the twentieth century. Others have countered this inference by showing that the substance in the ink that was thought to have become available only in the last century was available in the fifteenth century albeit as a constituent of another material. So no firm conclusion can be drawn. Still, if the map is indeed authentic then the credit for discovering the new world would have to go to the Norwegians, in particular to Leif Ericsson.

He is not the only pretender to that throne either. Followers of another Italian Americus Vespuccius or Amerigo Vespucci, as he is more popularly known, have argued that Columbus only reached the Caribbean islands. He thought that he had landed on the Indian soil and even proclaimed to be the case. That is how those lands are known today as the West Indies. He did not set foot on the American mainland until his third voyage in 1497. And he was beaten to the post by Amerigo. The land was called America in his honour. So America was really discovered in 1497.

Not to be left behind, now the Chinese have also come forward. Antiquities collector Liu Gang unveiled a map in Beijing saying it proves that Chinese seafarer Zheng discovered America more than 70 years before Christopher Columbus set foot in the New World. The map depicts all of the continents, including a small Australia, a roughed-out North America, and Antarctica. An inscription identifies the map as a copy made in 1763 of an original drawn in 1418. If verified, that date would coincide with the voyages of Zheng. He was an Admiral in the Ming dynasty's imperial navy. Zheng is known to have sailed as far as Africa between 1405 and 1433.

As if this confusion is not enough there are those who say that all this talk of 'discovery' of America is nonsense. America was inhabited by a number of 'Indians' well before Columbus or any of the other contenders ever started

thinking about these mysterious lands. A whole civilization had flourished there, especially in the Amazon basin. So, if at all, these Indians or rather their ancestors, who had migrated to America by the land route, should be considered as having discovered this continent. They are right of course. The word discovery is used in a Eurocentric manner, that is, from the viewpoint of the European colonisers.

So, where does it leave us? When was America 'discovered'? Well, 1492 and by Columbus should be the safest answer as far as any contestant in "Who wants to be a millionaire" is concerned. For the rest, watch this space.

44

WHEN WAS FIRE DISCOVERED?

Fire is considered to be the first discovery made by the human species. A discovery is said to be of a phenomenon or its cause that has been present in nature well before humans learnt of its existence. For example, gravitational force has been around ever since the beginning of the universe. Everyone had experienced its pull and observed the myriad phenomena that arose out of its existence. Yet before the legendary apple fell on Newton's head and ignited a spark of genius, mankind was blissfully unaware of it all. So we credit Newton with the discovery of gravitation.

Fire likewise has existed in nature for a long time. Humans had even seen it and hence were well aware of its presence. Anyone who saw a bushfire caused by lightning strike may have been awed by the upward leaping flames. Nevertheless, he or she cannot be said to be unaware of its existence. So it was not fire that was discovered by humanity. What was discovered by *Homo sapiens* was lighting of a fire at will and controlling it.

The question thus may need a semantic modification. Yet it begs an answer. When did humans discover the trick of igniting a fire on demand? It is not easy to answer that question. Still, recently two different groups of scientists have arrived at plausible solutions to this riddle.

Researchers from the Hebrew University in Jerusalem and Bar-Ilan University in Ramat-Gan excavated a waterlogged site at Gesher Benot Ya'aqov. They found numerous flint implements belonging to the so-called

Acheulean tradition of tool manufacture in deposits that were buried 34 m below the surface. Some of these were burnt, while others were not. The team mapped the distribution of the burnt and unburned artefacts and compared them. Although there was some overlap with the unburned artefacts, the burnt ones clustered together at specific spots at the site. The researchers think the clusters of burnt artefacts, which date to between 790,000 and 690,000 years before the present, indicate the sites of ancient camp fires, or hearths, made by either *Homo erectus* or *Homo ergaster*. But these were different species that can be

considered as evolutionary predecessors of modern humans. Could they have been a primitive form of *Homo sapiens*? The Israeli team cannot rule out that possibility.

The control of fire enabled dramatic changes in human diet, according to many an anthropologist. It also endowed humans with the ability to defend social groups against wild animals and aided social interaction. Plant remains at the site suggest the humans burned six types of wood, three of which—namely olive tree, wild barley and wild grape—are edible.

Sceptics have wondered how can one be sure that these fires were man-made and not natural. It is true that the latter possibility cannot be discounted. But a number of lines of evidence make this unlikely.

"They've got wood and other material around and that's not all burnt, so if someone said: 'Maybe these are hotspots caused by some big general fire', that's a good answer," said Professor Gowlett, a senior member of the research team. The fires also occur in lots of layers at the site, suggesting that they are close together in time. Professor Gowlett said the body of evidence suggested wildfires were more widely spaced in geological sequences.

This inference is supported by another find at the site of Swartkrans in South Africa. Burnt bones that are about 1.5 million years old have been unearthed at that spot. Similiarly, in nearby Chesowanga in Kenya, burnt patches of dirt that are about 1.4 million years old have been discovered. New data on the bones from Swartkrans using the technique of Electron Spin Resonance (ESR) appear to confirm that those dates are correct. ESR looks at free radicals, fragments of molecules produced by a variety of processes, such as radiation damage or fire. Studying the light signature, or spectra, produced by these free radicals can give scientists information on the nature of the damage.

It showed that the bones had been heated to high temperatures usually only achieved in hearths, possibly making it the first evidence of fire use by humans. These

bones could have been burnt in a forest fire or a bush fire, but that's generally a low temperature flame. These had been heated to a very high temperature. Forest or bush fires usually only reach temperatures of around 300 degrees Celsius. But hearths or campfires can reach temperatures of 600 degrees Celsius or more. As organic material, such as bone and collagen, is broken down by heating, the particles get smaller and smaller until only the carbon is left. The ESR data would seem to confirm original suggestions about the bones. This is because the degree of carbonisation of organic material as measured with ESR is dependent only upon the amount of carbon and not on the time that the material has been heated for.

It is not known which hominid species made the fires at Swartkrans. There seem to have been two hominid species present at Swartkrans around two million years ago. These were *Australopithecus* (or *Paranthropus*) *robustus* and an early species of *Homo*, possibly *Homo erectus*. The next oldest evidence for controlled use of fire may come from Zhoukoudian in China, dating to between 400,000 and 250,000 years ago.

So when was fire discovered? It was probably a million years ago that humans first started using controlled fire possibly for warmth, cooking as well as for protection from predators.

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WHEN WAS THE *MAHABHARATA* WAR FOUGHT?

Even before one ventures to grapple with this problem one would have to determine whether the epic war was a true historical event. If it was only a part of fiction, albeit much adored and adulated, then the question would be a non starter. It would be futile then to make any serious attempt to determine the date by any scientific method. Clues would have to found within the fictional text itself.

The point is debatable with no clear indication either way. Proponents of both sides have come up with a good many evidences. None of them, however, is confirmatory. Even so, the finding of submerged Dwarka at the precise location mentioned in the epic by the renowned marine archeologist S.R. Rao has tilted the argument in favour of it being a part of the ancient history.

That is why determining the time when the War was waged makes sense. Many famous astronomers like Aryabhatta (AD 476-550), Varahmihira (circa AD 560), etc. made serious efforts to date the *Mahabharata*. There have been many researchers attempting to solve this problem in the last 100 years. All of these revolved around deciphering the astronomical clues culled from the text.

Yet that was not easy. To verify the astronomical data, and come up with a definite date, was a very complex mathematical problem. The calculating abilities of the Indian astronomers of yesteryears were very limited as compared to the challenge posed by this problem. There have been several Indian astro-physicists who have also tried to solve

this problem but all in vain.

Recently fresh studies were undertaken, now that more modern techniques have become available. Also, computerised analysis of the data can be attempted. The objective of this work is to correctly identify the date of the War and to show that no other date is possible. This is carried out by minimising an objective function whose

variables are the errors in the positions of various planets including the node of the moon, known as *Rahu* in the common parlance, on the day of the *Kartik Purnima* as mentioned in the *Bhishma Parva* of the *Mahabharata*. .

After arriving at this minimum, the planetary positions of each of the days up to the *Uttarayana*, the winter solstice day, are calculated and checked for the matching descriptions of these positions with respect to the descriptions in the *Mahabharata*. The search time span begins from 500 BC to 4000 BC. This time span ensures that it covers all possible dates of the *Mahabharata* War. Finally, the date so determined is checked against other archaeological evidences such as the possibility of the presence of iron in India on that date. In this regard, other papers are cited as supporting evidences. In this way, it is established that this, and only this date, is the date of the *Mahabharata* War. This work, in establishing the historicity of the *Mahabharata*, is similar to the unearthing of the antiquities, a collection of pre-Mycenaean jewels and plates known as Priam's Treasure, by the German archeologist Henrich Schliemann in Turkey in 1870s.

The battle is said to have occurred before the transition of eons which can be roughly translated as *yuga*. The battle took place around the transition from *Dwapara yuga* eon to *Kali yuga* eon. Aryabhatta, the famous ancient Indian astronomer made attempts to estimate commencement of *Kali yuga*. His estimates of the time of moon revolution around the earth are so accurate, that his works are being extensively researched. There is also evidence to suggest he used zero in his work. Aryabhatta (AD 476–550) stated that *Kali yuga* started 3600 years before his time. He pronounced this, when he was 23 years old in the year AD 499. That works out to the beginning of *Kali yuga* as 3102 BC.

But this might be mere conjecture. The text of the *Mahabharata* itself contains two tell-tale descriptions of astronomical events. These can help a great deal in arriving at the correct date. One of these relates to retrograde motions

of many planets. But more remarkable is the mention of a pair of eclipses that occurred 13 days apart. This astronomical reference to "thirteen day" eclipse pair appears to be a unique astronomical observation. It also states that two eclipses occurred in one lunar month. A lunar eclipse can occur only on the full moon day while the solar eclipse can take place only on *Amavasya*, the no-moon day. One interpretation of the reference to a pair of eclipses thus would be that a lunar eclipse occurred first followed by a solar eclipse on the 13th day after the lunar eclipse.

Though such pairs of eclipses are known to have occurred, it is not such a common phenomenon. Thus a number of researchers have concentrated on finding out possible dates between 3400 BC and 700 BC. Further, these eclipses have had to be visible at Kurukshetra where the epic battle was fought. All the possible dates so arrived at are then cross-checked with other astronomical clues as well as available archeological data.

During the period of our interest, from 3500 BC to 700 BC, nearly 4350 lunar eclipses and 6960 solar eclipses have occurred. We need to search amongst these for eclipse pairs visible in Kurukshetra, which occurred in 13 days. Though solar eclipses are more in number, to be visible at a given location like Kurukshetra, they are relatively fewer. This is because of limited moon shadow size, while all the lunar eclipses are usually visible in most places. Hence for an observer at a given location, lunar eclipses appear to be more in number. We are more interested in eclipse pairs, occurring during consecutive full moon/new moon period that could be seen at Kurukshetra.

The research showed that nearly 673 solar and lunar eclipses occurred in pairs with a time gap of about 15 days corresponding to roughly half a lunar month. We need to search amongst these 673 for an eclipse pair visible in Kurukshetra, which occurred within "thirteen" days of each other.

This large list can, therefore, be narrowed down further

by checking the possible dates with the retrograde positions of some planets. By approaching the problem in such a reductionist mode six possible dates have been arrived at. These range from 3129 BC to 1397 BC. If one has to arrange them in order of merit, the most likely date is said to be 3129 BC and the one with the next highest probability is 2556 BC.

So, when was the epic *Mahabharata* War fought? It was waged sometime between 4500 and 5000 years before the present.

46

WHEN WAS THE SILOAM TUNNEL BUILT?

In the early years of the 21st century an ancient waterway that still carries water from the Gihon Spring into Jerusalem's ancient city of David was discovered. It was called the Siloam Tunnel because it fitted the description of a similar structure mentioned in the Bible. Immediately thereafter dispute arose regarding the precise date when it was constructed. If the Bible were to be believed then the aquaduct was constructed during the reign of the King Hezekiah—between 727 BC and 698 BC—to protect the city's water supply against an imminent Assyrian siege. Critics, nonethless, argued that a stone inscription close to the exit dates the tunnel at around 2 BC.

To solve the conundrum, geologist Amos Frumkin, of the Hebrew University of Jerusalem, and colleagues looked at the decay of radioactive elements, such as carbon in plants and thorium in stalactites, in tunnel samples. Radioactive dating techniques represent the most credible way of determining how old an object is.

That became possible only in the twentieth century when a brilliant young American chemist Willard Libby developed what came to be called as radioactive carbon dating. Libby was duly awarded the Nobel prize for his discovery. His method is called radiocarbon dating technique.

Radiocarbon dating determines the age of ancient objects by measuring the amount of carbon-14 that is still left in an object. Chemical elements have more than one type of atom. They are otherwise identical but differ in their weight. This

is because atoms of the same element can have different numbers of neutrons. The different possible versions of each element are called isotopes. For example, the most common isotope of hydrogen has no neutrons at all; but there's also a hydrogen isotope called deuterium, with one neutron, and another, tritium, with two neutrons. Hence, different atoms of the same element are the isotopes. Carbon has three main isotopes. They are one with the normal

atomic weight of 12, called carbon-12, a little heavier one with an atomic weight of 13, carbon-13 and the heaviest of the lot with atomic weight of 14, the carbon-14. Carbon-12 makes up 99 per cent of the total carbon, carbon-13 makes up 1 per cent and carbon-14 makes up just 1 part per million. Carbon-14 is radioactive and it is this radioactivity, which is used to measure age.

Radioactive atoms are unstable. They are eager to achieve stability by shedding some extra baggage that they are carrying. So they decay into stable atoms by emitting certain radiations. This process is governed by a mathematical relationship. A characteristic feature of this relationship is the half-life. It is the time period over which half of the total available radioactive atoms undergo a change by emitting radiation. Suppose a particular radioactive atom has a half-life of 10 years. If there were 1000 such atoms in the year 2000, then in 2010 there would be only 500 left. In another 10 years, that is in the year 2020, there would be 250 left, and in 2030 just 125 will remain.

By counting the number of carbon-14 atoms in any object with carbon in it, you can work out how old the object is or how long ago it died. So we only have to know two things, the half-life of carbon-14 and the number of carbon-14 atoms the object had before it died. The assumption is that the proportion of carbon-14 relative to that of carbon 12 atoms in any living organism is constant. So when a particular fossil was alive, it had the same amount of carbon-14 as the same living organism today. The half-life of carbon-14 is 5,730 years. By determining the proportion of carbon-14 atoms in the fossil, its age can be determined.

Therefore, if we have a box, and we don't know how old it is but we know it started with 100 carbon-14 atoms, and we open it and find only 50 carbon-14 atoms and some other stuff, we could say, "Aha! It must be 1 carbon-14 half-life (or 5730 years) old". This is the basic idea behind carbon dating.

So in the real world, looking at a sample like say a bone dug up by an archaeologist, how do we know how much carbon-14 we started with? That's actually kind of cool. In the atmosphere, cosmic rays smash into normal carbon-12 atoms, present in atmospheric carbon dioxide, and create carbon-14 isotopes. This process is constantly occurring, and has been going on for a very long time. So there is a fairly constant ratio of carbon-14 atoms to carbon-12 atoms in the atmosphere.

Now living plants 'breathe' CO_2 indiscriminately. They don't care about isotopes one way or the other, and so, while they are living, they have the same ratio of carbon-14 to carbon-12 in them as that in the atmosphere. Animals, including humans, consume plants a lot. Thus they also tend to have the same ratio of carbon-14 to carbon-12 atoms. This equilibrium persists in living organisms as long as they continue living. But when they die, they no longer 'breathe' or eat new carbon-14 atoms. Now it's fairly simple to determine how many total carbon atoms should be in a sample given its weight and chemical makeup. And given the fact that the ratio of carbon-14 to carbon-12 in living organisms is approximately $1 : 1.35 \times 10^{-12}$, we can figure out how many carbon-14 atoms were in the sample when it ceased to replenish it's supply.

Obviously, this technique only works for dead organic material. This technique is best for dating items, which died between say, a 1000 and a 1,000,000 years ago. Carbon-14 dating is not great for dating things like a year old because if much less than one half-life has passed, barely any of the carbon-14 would have decayed, and it is difficult to measure the difference in rates and know with certainty the time involved. On the other hand, if lots of half-lives have passed, there is almost none of the carbon-14 left. It is really hard to measure accurately the miniscule amount of carbon-14 that may still be there. Since it is not possible to predict exactly when a given atom will decay, one has to rely on statistical methods in dealing with radioactivity.

While this is an excellent method for say, a zillion atoms, it fails when one doesn't have good sample sizes. However, it is possible to use other longer lived isotopes for dating on a longer time scale. Dates derived from carbon samples can be carried back to about 50,000 years. Potassium, thorium or uranium isotopes, which have much longer half-lives, are used to date very ancient geological events that have to be measured in millions or billions of years.

Using such techniques it was found that the plaster lining the Siloam tunnel was laid down around 700 BC. A plant trapped inside the waterproof layer clocked in at 700–800 BC, whereas a stalactite was formed around 400 BC. "The plant must have been growing before the tunnel was excavated; the stalactite grew after it was excavated," explains Frumkin.

Thus one is in a much better position to say when the Siloam Tunnel was built. It was built around 2700 years before the present.

47

WHEN WAS WRITING INVENTED?

Reading, Writing and Arithmetic constitute the three basic R's that determine a person's educational status. A society that is proficient in all the three in a major way qualifies to be considered cultured. Indeed these faculties have differentiated humans from other primates of the animal kingdom to which *Homo sapiens* belong.

Which one of the three should take precedence? For a new learner, of course, reading comes first. Writing follows with arithmetic bringing up the rear. That is logical enough. Even programs aimed at improving adult literacy follow the same sequence. That might give an impression that reading evolved before the other two. That would be erroneous. For what would one read if there is nothing written down? That is why the oral tradition of learning had held sway for a long time with very few of the ancient texts written down at the time they had been compiled. Even for arithmetic, until writing was invented, counting as well as other basic operations were restricted to smaller numbers for which digits on hands and feet sufficed. It took big leaps and reached greater heights only after it became possible to jot down the numbers and work on them further.

The invention of writing then should be considered a highly significant landmark in the cultural evolution of humankind. Naturally, one would be interested to know at what time this important transition was brought about. When was writing invented?

That question cannot be addressed until we find out

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compelling reasons that necessitated such an invention. What prompted our ancestors to move away from the oral tradition that had served well until then and resort to writing down information. One can think of all the creative pursuits now associated with writing as having triggered that revolutionary undertaking—epics like the *Mahabharata* or the *Ramayana*? *Iliad* or *Odyssey*? Travelogues describing strange customs and practices one encountered when exploring new realms?

Today we would consider any of these forceful enough to have led someone to invent writing. Archeologists and ancient historians disagree. According to them the most pressing need is to be found in more mundane matters. Writing, the most important milestone, recorded independently as many as five times, was rooted in the need to run empires. Instead of the *shloka* describing the splendour of almighty, think divvying up real estate. Hamlet? No dice. How about lists of who paid what taxes? And forget the *Arthashastra*. Let's write tables of masons, farmers, kings and astrologers.

The inhabitants of ancient Mesopotamia, where Iraq now stands, are usually credited with the invention of writing. Clay tablets from slightly before 3,000 BC show a predecessor of the script called 'cuneiform', which records the affairs, and presumably the language, of the early Babylonians.

But did writing really originate on the banks of the Tigris and Euphrates rivers? Not according to archaeologist Günter Dreyer, Director of the German Institute of Archaeology in Cairo. If he's right, the Earth-shattering invention occurred on the banks of the Nile.

Dreyer said he'd found writing on a group of small bone or ivory labels dating from 3,300 to 3,200 BC. The labels were attached to bags of linen and oil in the tomb of King Scorpion I in Egypt. They apparently indicated the origin of the commodities.

Writing, here, means a symbolic representation of

language, not pictures, representing concrete objects.

Of course, archaeologists have uncovered objects or tablets containing some inscriptions that belong to an earlier period. Those inscriptions, however, are not considered writing. They are pictographs. Pictographs, however, are not truly writing, but rather drawings that represent specific words or objects. Writing and pictographs may look similar to our untutored eyes, but pictographs represent concrete objects or specific information. Thus a pictograph of an eye might stand for an eye, and a tooth for a tooth, an ox simply represents an ox, and a mark on a pot tells us "made by so and so."

In contrast, writing can represent everything, well, the verbal part, anyway, that comes from our mouths. Writing is so handy that, according to the conventional wisdom, it was probably invented many times: in Mesopotamia, Egypt, China, India and Central America.

That is why Dreyer maintains that the labels he's studied carry inscriptions with phonetic significance. That would make them a symbolic representation of language, true writing. And if he's right, they are the earliest known writing. Almost. In fact, he says the labels helped him decipher earlier inscriptions on pottery found in the same cemetery. If Dreyer is right, these inscriptions, dating from 3400 to 3,300 BC, are the first known writing. The Sumerians, inhabitants of ancient Babylonia, are generally thought to have beaten the Egyptians to the scribbling trade by a century or two. Now comes Dreyer's claim that ancient Egyptians were writing a century or two before the Sumerians.

So, now we can come back to the original question. When was writing invented? It was some five and half thousand years before present.

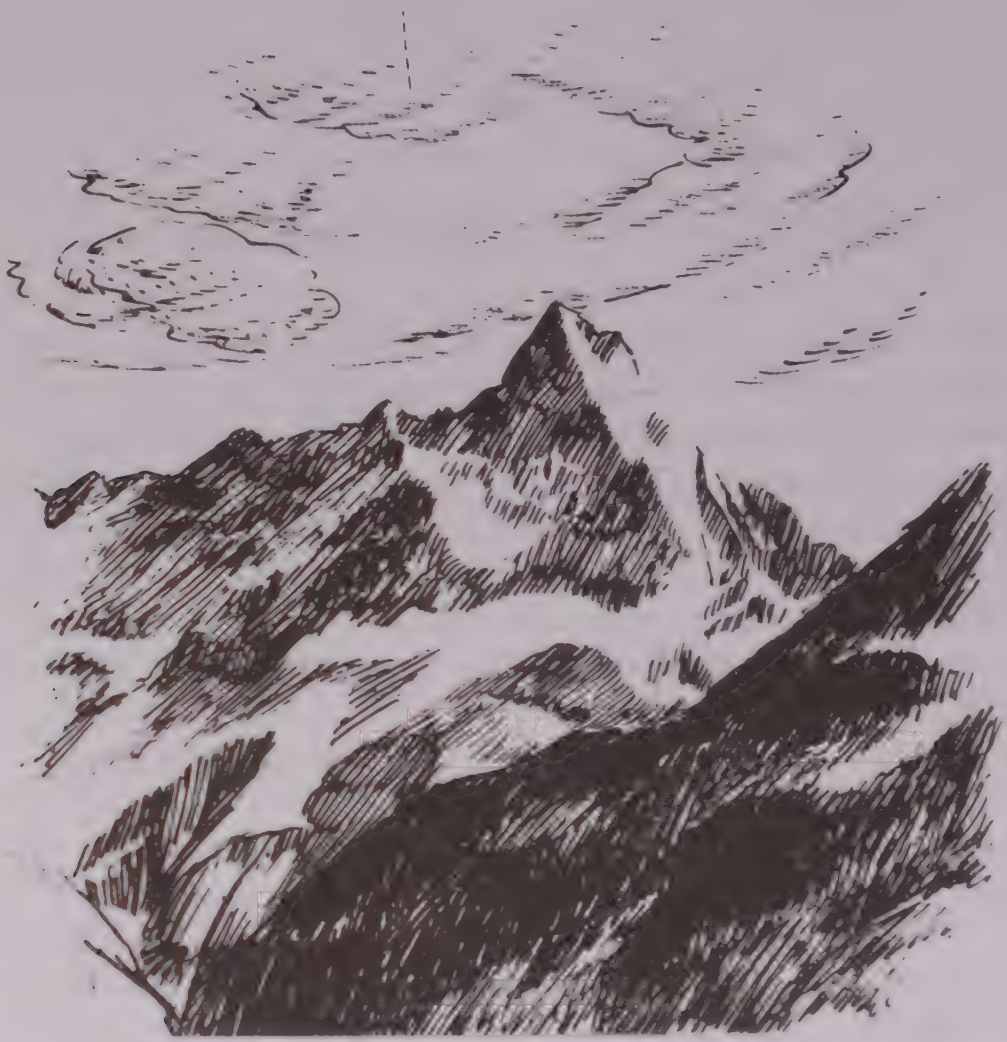
48

WHEN WERE THE HIMALAYAS BORN?

Awed by the grandeur and majestic appearance of the Himalayas, we have always considered it to be our natural fortification against invasions from the north. Ancient Sanskrit literature is full of descriptions of India as the land that has the great mountain as its northern boundary. In considering the ranges as impenetrable fortification endowed by Nature, we have always ignored the historical evidence that almost all the foreign invaders have entered the country through the Khyber Pass. Given the fact that most of the great rivers have their origins in these massive ranges the Himalayas have come to occupy almost a divine place in our psyche. That is perhaps the reason that we have taken it for granted that it has always been there.

It may come as a surprise, therefore, that this is far from true. The great northern ranges of the Himalayas are one of the latest additions to our country's topography. Even on the world stage the Himalayas constitute one of the youngest mountains. Naturally, one would then want to know when it was 'born'.

Once upon a time, the Earth was rather ill defined. It lacked the structure that embellishes it today. All that the Earth had on its surface was vast quantities of water. The oceans occupied almost all of its surface. A huge landmass, nonetheless, was there. It lay cuddled in the south-eastern corner of the Earth roughly where one finds Australia today. It stayed there in a huddle as if like a terrified child that is trying to escape attention of a ferocious demon. This was the supercontinent that one talks about. It was called



Pangaea, which is a Greek word meaning 'all lands'.

That situation prevailed for a long long time. Then, around 225 million years ago Pangaea sort of stirred out of its slumber. With this process of 'waking up' it started breaking apart. This resulted in the formation of two huge continents, Laurasia to the north and Gondwanaland to the south. They started drifting away from each other. Over the next 25 million years they had completely separated from each other with the Tethys sea occupying the space between them. This process continued. The distance between these two major continents kept increasing. Laurasia kept moving

in the north westerly direction. Gondwanaland moved a little towards the south east but not much.

The process gained further momentum and around 135 million years before the present these two huge continents also started splitting further into smaller fragments. Out of Laurasia formed Europe and North America though they were still joined together. A large chunk of Gondwanaland broke away and moved towards the north east. This contained Africa and South America. The remaining portion of Gondwanaland broke into three pieces. The smallest of these cut off its linkage with the others and formed an island in the Tethys sea. The other two pieces remained holding on to each other though precariously.

Having tasted wanderlust these continents kept moving away from each other. Around 65 million years ago, that is around the time the dinosaurs were getting obliterated from the face of the Earth, South America finally detached itself completely from Africa and moved westwards. Africa travelled northwards to join hands with the southern tip of Europe. North America finally waved goodbye to Europe and went in the westerly direction. The two pieces of Gondwanaland that still hung on to each other could no longer stay together. They set off on their individual sojourns. The western portion moved south and formed Antarctica. The eastern part formed Australia and shifted in the north easterly direction. The lonely piece that had found itself totally surrounded by the Tethys sea wanted to end its isolation. So it raced northwest and dashed into the Asian continent. That was the subcontinent of India.

Nobody was aware of this story of the wandering continents till the beginning of the twentieth century. The possibility that continents have not always been fixed in their present positions was suspected long before the 20th century. It was first suggested as early as 1596 by the Dutch map maker Abraham Ortelius in his work, *Thesaurus Geographicus*. Ortelius proposed that the Americas were "torn away from Europe and Africa by earthquakes and

floods" and went on to say: "The vestiges of the rupture reveal themselves, if someone brings forward a map of the world and considers carefully the coasts of the three continents." Ortelius' idea surfaced again in the 19th century. However, it was not until 1912 that the idea of moving continents was seriously considered as a full-blown scientific theory, called 'Continental Drift'. This concept was introduced in two articles published by a 32-year-old German meteorologist named Alfred Lothar Wegener.

Before Wegener enunciated his theory of continental drift it was thought that the formation of mountains was an inevitable part of the process of cooling of the Earth. The surface cracked and folded onto itself. The mountains thus were considered to be these folds. If that were true then all these folds should have occurred at the same time. In other words, all mountain ranges should be approximately of the same age. But this was known not to be true. Different mountains appeared to have been formed at different times. Obviously, it was necessary to consider some other ideas about the manner in which they could have been formed. Wegener's theory had provided just such an alternate explanation. He had proposed that as the continents moved, the leading edge of the continent would encounter resistance and thus compress and fold upwards. If you were to move a piece of paper along the floor it stops moving the moment it encounters a wall. The paper experiences a resistance to its further movement. If you tried to force its way the front edge of the paper starts crumpling and folding on itself. That edge also gets raised forming a hillock. Something similar would happen to the moving plates. Mountains would then be formed near the leading edges of the drifting continents.

Wegener also suggested that among the most dramatic and visible creations of plate-tectonic forces are the lofty Himalayas. By studying the history, and ultimately the total disappearance, of the Tethys ocean, scientists have reconstructed India's northward journey. About 80 million

years ago, India was located roughly 6,400 km south of the Asian continent, moving northward at a rate of about 9 m a century. When India rammed into Asia about 40 to 50 million years ago, its northward advance slowed by about half. The collision and associated decrease in the rate of plate movement are thought to have marked the beginning of the rapid uplift of the Himalayas.

Normally whenever two plates collide with each other the weaker one is forced down under the other. Because the continental landmasses of both India and Asia have about the same rock density, one plate could not be pushed under the other. The pressure of the impinging plates could only be relieved by thrusting skyward. We often see pictures of two running trains colliding with each other in a ghastly accident. These show that the bogies of the two trains have tried to climb on to each other. The same was the fate of these huge landmasses. The upward movement would have caused contortions in the area where the collision was taking place. That gave rise to the jagged Himalayan peaks.

The point where the two continents, Asia and India, were joined is known, appropriately, as the Indus-Yarlung Suture zone, marked by the courses of these two greatest rivers of the Kailash. After 60 million years, the Indian and Asian plates became closely welded along this suture zone. The northward movement of India continued but at a slower rate, 2–3 centimetres per year.

Thus were the Himalayas born. And what birth pangs! As a result of the collision itself, and the related contraction of the Tethyan ocean, all the rocks of this area, from the mountains of then northern India to the oceanic crust, and the deep sea sediments of the Jurassic and Cretaceous ages—joined in the formation of the Himalayas.

The Himalayas as we see them today went through some distinct epochs of uplift. First came the Trans-Himalaya. South of this is the high Himalayan region, where the range reaches its highest points. Here we find old crystalline rock, the oldest core material in the entire

Himalayas, almost 2 billion years old, the bottom layers of the compacted Tethyan sediments. This is known as the main central thrust.

As the Himalayas rose, the forces of erosion kept pace, leading to the formation of a contiguous lower range of hills known as the Shivaliks. Made of erosion material from the still rising Himalayas, their sediments reflect the history of the upthrust of the emergent Himalayas. Numerous fossil finds allow the Shivaliks to be dated with accuracy and provide evidence of the comparative youth of the Himalayas.

In the second phase of upheaval, further uplift of the central axis took place. It was now that the great peaks of the Garhwal Himalaya, Nanda Devi etc., achieved their present eminences. In this period, intrusions of young granites, known as leucogranites because of their whitish colour, took place in the highest peaks, such as the Bhagirathi sisters and Shivaling.

The last upthrust affected not only the Himalayas, Trans-Himalaya and the Karakorum, but also the whole of the Tibetan region. With an area of 2.5 million square kilometers, this region is the highest land mass on earth and in the last 1 million years it has risen by nearly 5,000 meters, an average of 4–5 millimeters per year. The uplift continues even today at a measurable 10 meters every hundred years. Mount Everest has itself risen 8.2 meters in the last 100 years.

So, when were the Himalayas born? They were born around 40–50 million years ago. But the birth process is not complete yet. It continues even today.

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WHEN WOULD THE NEXT EARTHQUAKE OCCUR?

Well, your guess is as good as mine. That would be the most appropriate answer. No doubt earthquake science has taken impressive strides over the past century. For one, we have developed the theory of plate tectonics. It tells us that the earth's crust is not one endless cover that we thought it was. On the contrary, it is made up of a number of different plates that are continuously on the move. In the process they collide against each other, rub each other the wrong way, try to slip past their neighbours, and adopt some rough arm tactics when that is not made easy. All these larks on the part of these plates are potential triggers for the earth to throw a tantrum and perform the *Tandava*. We know that now.

We are also able to track the seismic waves that travel through the interior of the earth prior to as well as after an earthquake. We can also measure the intensity of the quake. The Richter scale has been developed for the purpose. It was invented by Charles F. Richter in 1934. The Richter magnitude is calculated from the amplitude of the largest seismic wave recorded for the earthquake.

The Richter magnitudes are based on a logarithmic scale (base 10). What this means is that for each whole number you go up on the Richter scale, the amplitude of the ground motion recorded by a seismograph goes up ten times. Using this scale, a magnitude 5 earthquake would result in ten times the level of ground shaking as a magnitude 4 earthquake, and 32 times as much energy would be released.

To give you an idea how these numbers can add up, think of it in terms of the energy released by explosives: A magnitude 1 seismic wave releases as much energy as blowing up 170 gm of TNT. A magnitude 8 earthquake releases as much energy as detonating 6 million tons of TNT. Pretty impressive!

Earthquakes measuring 6 or less on this scale cause at most slight damage to well-designed buildings. But they can bring about major damage to poorly constructed buildings over small regions. Those having a magnitude between 6 and 7 can be destructive in areas up to about 100 kilometers across. Any event measuring over 7 can be deemed to be a major earthquake. One with a still higher intensity that tips the scale at 8 or higher is decidedly a great earthquake. It can lead to serious damage in areas several hundred kilometers across.

All this is well understood now. Yet we are nowhere near accurately predicting when exactly the forces accumulating along fault lines would cross the threshold and let loose the trapped energy. We can at best identify the earthquake prone regions and keep a constant vigil. Even so, it does not help us issue a warning in advance so as to minimise loss of life or limb.

One of the reasons for this inability to tell in advance about an earthquake is that faults don't follow neat and orderly lines across the landscape. There are places, such as southern California, where they look like a shattered windshield. All that cracked, unstable crust seethes with stress. When one fault lurches, it can dump stress on other faults.

This is most distressing because earthquakes kill people. They level cities. The tsunami of 26 December 2004, in Banda Aceh spawned by a giant earthquake, annihilated more than 220,000 lives. The magnitude 7.6 quake centred in Kashmir, in October 2005, killed at least 73,000 people. Perhaps as many as a million would be dead or injured if a major quake felled the unreinforced high-rise structures of

Tehran, Kabul, or Istanbul. One of the world's largest economies, Japan, rests nervously atop a seismically rambunctious intersection of tectonic plates. A major earthquake on one of the faults hidden underneath Los Angeles could kill ten thousand people.

Yet, at the moment, earthquake prediction remains a matter of myth, of fables in which birds and snakes and fish and bunny rabbits somehow sniff out the coming calamity. What scientists can do right now is make good

maps of fault zones and figure out which ones are probably due for a rupture. And they can make forecasts. A forecast might say that, over a certain number of years, there's a certain likelihood of a certain magnitude earthquake in a given spot.

Ideally a prediction would specify the time, place, and magnitude of the next earthquake. With current information, this is about as easy as predicting the next traffic accident in a large city like Mumbai. A specific traffic accident cannot be predicted, but experience shows that accidents are more likely during evening rush hours. They also occur more frequently on certain streets and more often involve two rather than ten cars. Similarly, the pattern of past earthquake activity can be used to estimate how often and where earthquakes of a given magnitude and location are likely to occur in the future. With the addition of geologic information, we can refine the estimate of where these earthquakes might occur.

People have tried to associate an impending earthquake with such things as animal behaviour, electromagnetic fields, weather conditions, unusual clouds, radon gas in ground water, water level in wells and so on, thereby suggesting that the dataset of observed seismicity is dependent on a large number of external variables. Controversy arises as a result, since conclusions usually should not be made from a small data set unless a well understood physical phenomenon is present, particularly when the data set is noisy or there are questions regarding how it is gathered.

Chinese earthquake prediction research is largely based on unusual events before earthquakes, such as change of ground water levels, strange animal behaviour and foreshocks. They successfully predicted the 7.3 magnitude earthquake that occurred at Haicheng on 4 February 1975. At that time the China State Seismological Bureau ordered evacuation of one million people the day before the earthquake. However, they failed to predict the 7.8 magnitude earthquake that shook Tangshen a year later.

This failure put Chinese earthquake prediction research in doubt.

Some people believe that there is evidence that animals sense the immediate onset of earthquakes. In support of this claim instances are cited when people have witnessed flight of animals just before an earthquake disaster. In fact, according to the Chief conservator of forests for Tamil Nadu, a few minutes before the killer tsunami waves generated by an underwater earthquake hit the Indian coastline in December 2004, a 500 strong herd of black bucks rushed away from the coastal areas to the safety of a nearby hilltop. Since the beginning of recorded history, observations of unusual animal behaviour before earthquakes have been recorded by people from almost all civilizations. The Chinese began a systematic study of this unusual animal behaviour. This helped them, in December 1974, predict the Haicheng earthquake that did, in fact, occur in February 1975. Still, it has to be agreed that this method is ambiguous and cannot yet pass muster as a scientifically accurate technique.

So where does it leave us? Do we know for sure when the next earthquake would occur? And where? Honestly, we do not know.

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WHEN WOULD MANKIND BECOME EXTINCT?

"How many crows are residents of Delhi?" This was the question, we are told, Akbar, the Mughal emperor of India had put to the legendary sagacious Birbal. *Badshah*, the emperor, was forced to ask such an outlandish question at the behest of his courtiers who could not quite stomach the adulation that the king was bestowing on his most favourite wise man. The courtiers thought that even Birbal would be quite flummoxed by this unusual query and would be brought down a peg or two in the esteem of the king.

Birbal, however, quiet nonchalantly lost no time in coming up with his reply. He quoted some large figure running into hundreds of thousands. Even the king was incredulous and gave vent to his astonishment by asking how could Birbal be so sure of the accuracy of his statement. To which the wily sage came up with a rejoinder, "I have no doubt whatsoever that I am right. Anyone who doesn't believe me can go count for himself." Observing that a sudden silence had descended on the court he went on to add, tongue firmly placed in cheek, "If the actual number turns out to be higher than the one I have stated it must be due to arrival of some guests from outside. On the other hand, if the actual count is lower, that can be accounted for by the fact that some of the residents have gone out on business or for pleasure".

Birbal could be excused for employing this strategy of tit for tat. A cunning question deserves a crafty reply. To Sir Ronald Fisher, the redoubtable statistician, this was unacceptable. He was aware that a similar question, weird

as it seemed on the face of it, was being raised by ornithologists trying to count the number of bird species in the Malaysian rainforests, in all innocence and seriousness. He, therefore, decided to wrestle with it in a scientific manner. In the end he came up with a path breaking theory that showed the way of addressing such vexing problems.

That is why when Richard Gott, the Princeton physicist, was challenged with the question: What is the total life span of the human species?, he did not dismiss it out of hand. He accepted the challenge and resorted to adopting the Fisher theory. In addition, he employed the Copernican principle as underpinnings to his quest.

Copernican principle is the main principle of cosmology. As applied to the Universe it states than neither our place in the Universe nor orientation of the Solar system nor our time is in any way special. The term originated in the paradigm shift from the Ptolemaic model of the heavens, which placed Earth at the centre of the Solar system because it appeared to them that everything revolved around Earth. Nicolaus Copernicus demonstrated that the motion of the heavens can be explained without the Earth, or anything else, being in the geometric centre of the system. So the assumption, that we are observing the celestial movements from a special unique position, can be dispensed with.

Once this change of mindset takes place it becomes easy to look at everything in an objective fashion. Once we accept that there is nothing special about the human species then it follows that all the natural principles, laws, regulations that have governed the rise and fall of all the other myriad species apply equally to *Homo sapiens*.

Since life originated on earth some three and a half billion years ago, a number of animal and plant species have emerged, survived merrily for a while and withered away. Even the mighty dinosaurs which ruled over the world for close to 100 million years eventually became extinct. Notwithstanding the brave efforts of Michael Crichton and Steven Spielberg to bring them back to life,

albeit in the celluloid world, there is no trace of them anywhere on this globe. The ancient Hindu triad of *utpatti, sthiti* and *laya*—i.e. genesis, survival and extinction—that has governed the status of all the species should equally decide the fate of the human species as well.

So Gott looked at the life history of all the species, including other primates and hominids, that emerged, ruled roost for a while and died away during the course of evolution. He based his calculations on this study and hypothesised that the entire lifespan of any species can be divided into forty segments or periods. The probability of a species being in any one of them is two-and-a-half per cent.

The human species has been in existence for about 200,000 years. Suppose it is in the very first of the 40 periods of its overall life span. Then it would mean that is has a likelihood of continuing on for another 39 periods of equal length. In other words, it would continue to dominate the world for 39 times the present age. So it would be very much there for 7.8 million years.

On the other hand, suppose it is in the 40th and last segment of its total life span then it would be able to pull on for another 2.5 per cent of its present age. That would work out to 5120 years. So, a good estimate of the remaining period of its existence would be somewhere between 5000 and 8 million years.

Theoretical though Gott's arguments are, they are based on credible scientific tenets. A more interesting observation is that unlike our close genetic relatives, the chimpanzees, all humans have virtually identical DNA. In fact, one group of chimpanzees can have more genetic diversity than all of the six billion humans alive today. The absence of those differences suggests to some researchers that the human gene pool was reduced to a small size in the recent past, thereby wiping out genetic variation between current populations.

The study suggests that at one point there may have been only 2,000 individuals alive as our species teetered on

the brink. This means that, for a while, humanity was in a perilous state, vulnerable to disease, environmental disasters and conflict. If any of these factors had turned against us we would not be here. Humans may have come close to extinction about 70,000 years ago.

So when would the human species be extinct? Since it did not do so some 70,000 years ago, it would continue to be around for at least another 5000 years, if not for more than 7.5 million years.

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"When was writing invented?", "When does a child start recognising faces?", "When do we dream?" … . The list of such questions is endless. Some of them are mundane experiences. Many are related to scientific phenomena. Still others are philosophical. Whatever their nature, scientists not only handle them with the respect they deserve, but also attempt to satisfy our curiosity with perfectly logical and scientifically acceptable answers.

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A prolific freelance science communicator, **Bal Phondke** obtained his doctorate in Biophysics-Immunology from London University. He began his career as a research scientist in BARC. Later, he was the chief editor of *Science Today*, Science Editor of the *Times of India* group of newspapers and then the Director of National Institute of Science Communication (CSIR). He has more than 50 published books to his credit and his columns are featured in almost all leading Marathi newspapers. Dr Phondke has been honoured with the NCSTC National Award, the INSA Indira Gandhi Award for best science popularisation, as well as the B.C. Deb Memorial Award from the Indian Science Congress.

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